Masters Program in **Geospatial Technologies**

PROVIDING ENERGY EFFICIENCY LOCATION-BASED STRATEGIES FOR BUILDINGS USING LINKED OPEN DATA

Ana Sanchis Huertas

Dissertation submitted in partial fulfilment of the requirements for the Degree of *Master of Science in Geospatial Technologies*

UNIVERSIDADE NOVA ISEGI
UNIVERSITAT JAUME·I
WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER

PROVIDING ENERGY EFFICIENCY LOCATION-BASED STRATEGIES FOR BUILDINGS USING LINKED OPEN DATA

Dissertation supervised by:

Professor Miguel Neto, Ph.D.

ISEGI – Universidade Nova de Lisboa

Professor Rafael Berlanga, Ph.D.

INIT – Universitat Jaume I de Castellón

Professor Albert Remke, Ph.D.

IFGI – Universität Münster

March 2012

ACKNOWLEDGMENTS

To my family, my most important support in all the challenges in my life.

To my supervisors, for their valuable comments and guide.

To my professors, opening my eyes to new things.

To my friends, being there.

To all those who inspire, help and advice.

PROVIDING ENERGY EFFICIENCY LOCATION-BASED STRATEGIES FOR BUILDINGS USING LINKED OPEN DATA

ABSTRACT

Climate change is a main concern for humanity from the ending of 20th century. To improve and take care of our environment, a set of measures has been developed to monitor, manage, reduce consumption and raise efficiency of buildings, including the integration of renewable energies and the implementation of passive measures like the improvement of the building envelope.

Complex methodologies are used in order to achieve these objectives. Using different tools and data translating is needed, and the loss of accuracy from the detailed input information is most of the times unavoidable. Moreover, including these measures in the development of a project have become a try and error process involving building characteristics, location data and energy efficiency measures.

The raising of new technologies, capable of dealing with location-based data and semantics to relate and structure information in a machine readable way, may allow us to provide a set of technical measures to improve energy efficiency in an accessible, open, understandable and easy way from a few data about location and building characteristics. This work tries to define a model and its necessary and sufficient set of data. Its application will provide customized strategies acting as pre-feasibility constraints to help buildings achieve their energy efficiency objectives from its very conception. The model intends to be useful for non-expert users who want to know about their energy savings possibilities, and for professionals willing to get a sustainable starting point for their projects.

KEYWORDS

Building Systems

Climate Change

Data

Energy Efficiency

Energy Performance

Environmental Constraints

Decision Support Systems

Geospatial Technologies

Geographical Information Systems

Location

Semantic Web

Linked Open Data

ACRONYMS

AEMET: Spanish Agency for Meteorological Data

B.C.: Before Christ

BIM: Building Information Management

CTE-DB-HE: Technical Building Code – Basic Document – Energy Saving

FIDE: Building Data Interchanging Format

GIS: Geospatial Information System (Science)

HVAC: Heating, Ventilation and Air Conditioning

HTTP: Hypertext Transfer Protocol

IFC: Industry Foundation Classes

IPCC: International Panel on Climate Change

LOD: Linked Open Data

OGC: Open Geospatial Consortium

PV: Photovoltaic

RDF: Resource Description Framework

RES: Renewable Energy Source

SDI: Spatial Data Infrastructures

SPARQL: SPARQL Protocol and RDF Query Language

URI: Uniform Resource Identifier

W3: World Wide Web Consortium

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

"In the winter, that seat is close enough to the radiator to remain warm, and yet not so close as to cause perspiration. In the summer, it's directly in the path of a cross-breeze created by opening windows there and there. It faces the television at an angle that is neither direct, thus discouraging conversation, nor so far wide as to create a parallax distortion. I could go on, but I think I've made my point."

Dr. Sheldon Lee Cooper - The Big Bang Theory Pilot

1. INTRODUCTION

1.1. Motivation

Climate change is a main concern for humanity from the ending of 20th century. Human activities affect environment and consume resources with limited lifetime. One of these activities is the process of construction and use of buildings. In 1990, the residential, commercial and institutional buildings sector was responsible for one-third of global energy use and associated carbon emissions (Watson et al., 1996).

In this context, most efforts are done in the scope of the building contribution to pollution, paying attention to the whole building life cycle, from the site election and the natural resources involved, the materials, construction processes and tools, the appliances installed and the energy sources, to the use performed by people during its life (Kim et al., 2010). Initiatives are carried on in international meetings like the Intergovernmental Panel on Climate Change (IPCC) where governments and institutions develop rules from global to local concerns, defining variables and objectives to achieve (UNGA, 1998).

These objectives are intended to be achieved by countries and supranational institutions defining framework legislations and measures to be implemented during the building lifetime. In this sense, the "Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings" defines a set of variables to take into account to monitor, manage, and finally reduce consumption and raise energy efficiency of buildings (COM 2002/91/EC).

These variables are developed by European countries in their national legislations, defining how to achieve objectives with concrete measures and measuring methods, which include, among other things, the integration of renewable energy sources (RES) and the implementation of passive measures like the improvement of the building envelope, depending on building types and climatic conditions (RD 47/2007).

1.2. Problem

In order to calculate and define how to implement measures and achieve energy related objectives, different tools and complex methodologies have been developed on top of the regular projecting process, where not all of them provide same functionalities, provoking several problems (Crawley et al. 2008). Since there is no tool performing all necessities mentioned by legislation, the use of different tools is needed to cover the complete range of measures recommended. Moreover, since these tools are not an integrated part of the projecting process but a supplement, the energy performance calculation need always more than one tool. The independency and heterogeneity of these tools provokes the need of data translation, for the sake of interoperability, resulting on a consequent loss of accuracy and a long, complex transformation process, increasing error rate. possibility of error appearance.

A classic architectural project follows Vitruvius's axiom "*Utilitas, Firmitas, Venustas*". A global conception from first century B.C. validated through time until the present days. But there is no "*Sostenibilitas*" in this axiom, making energy performance calculation a try and error process involving building characteristics, location data and energy efficiency measures, where first the building is defined and, afterwards, its energy performance is checked. If the building fails its desired classification, a failure notification is sent, but in many cases, not a reason or alternative solution is provided, so going back is needed, then changing some parameters based usually on intuitions, and starting again, becomes the regular process.

On the other hand, we are always asked to introduce a huge amount of detailed information, which is not available and understandable for non-expert users, what makes energy management of their own homes and buildings an inaccessible process. Moreover, these data are processed with complex algorithms, to finally get a classification certificate, out of 6 possibilities, which seems a too simple result to get, compared to the complexity of the input data and processes applied. These data needed are not often available in an open an public manner, instead being published through interoperable components in open information systems, such as Spatial Data Infrastructures (SDIs) they remain in local silos being difficult to be found and integrated in other software applications. Moreover these data lacks of semantic descriptions which makes a hard task to consume it automatically.

Some tools integrate data from very different sources and provide a wide range of calculations and alternative solutions, but they are often proprietary tools, where high fees are demanded and almost none of them act as a pre-feasibility tool to avoid the uncertainty of verifying the defined project performance. Furthermore, these tools are prepared to deal with their own data encodings, facing some interoperability issues when trying to access and exploit a set of heterogeneous data. Finally, they work with non semantic data, so you are not allowed to discovery related data or even interpret the similarities or differences within available data.

1.3. Context

The raising of new technologies capable of dealing with location- based data, like climate or soil data, both interesting and needed in this work, is an important achievement for data providing and processing. Many efforts are being done in the standardization of this type of data, like the Open Geospatial Consortium standards and specifications (Schell et al. 2000), and its availability, like with the deployment of Spatial Data Infrastructures, information systems based on standardized web services to manage and share geospatial data and tools.

In the building context, the development of the Building Information Modelling (BIM) facilitates the comprehension of buildings composition, relations and functionality. The materials catalogue defined as XML standards like FIDE (AIDICO, 2011) or the cities models and buildings defined with CityGML (Gröger et al. 2008) are some examples.

Also introducing and improving semantic content within data, to relate and structure information in a machine readable way will help users to find, share, and combine information more easily. In this context, he World Wide Web Consortium (w3) or Linked Data initiative define standards and methodologies which will help our goal of linking data from very different sources to get more useful results (Heath et al. 2009). Efforts are done in the field of climate data, like Aemet data, provided as LOD (http://aemet.linkeddata.es/index.html), or, in the field of housing definition, the DogOnt ontology for domotic systems (Bonino and Corno, 2008).

1.4. Contribution

This work tries to define a model whose application provides customized strategies which will act as pre-feasibility constraints to help a building to achieve its energy efficiency objectives from its very conception. Early design decisions may not require a detailed simulation program or a suite of tools which would support a range of simulation needs (Crawley et al. 2008) but one simple tool covering all simulations in a general way.

The idea is to model available data in a way that, from very simple data like location, use, orientation or area, non expert users will be able to get a set of energy efficiency strategies like building envelope materials and constructive systems or potential power available from renewable energies systems.

The objective is to find out which data are necessary and sufficient to get a result; which ones must be provided by users, and which ones are available by other means an where. Then, find out how these data can be connected to perform together. And finally, what are the operations that these data have to complete to get a useful result.

For doing so, the energy demand limitation verification process and the energy performance classification process will be studied and a simplified step by step process will be proposed. Then all data needed as inputs and outputs in each step will be set, and its origin will be studied. The relations needed between data to perform together will be modeled and a vocabulary for missing terms will be built and exposed as LOD.

The expected result may serve to allow the development of an application on top of this model that should act as a pre-feasibility on-line open tool to provide information in an accessible, open, understandable and easy way.

The intended simplicity of data needed, makes this model useful for general public wanting to know about their energy savings possibilities before starting a new project or refurbishment, as well as to professionals willing to have a starting point for their project, avoiding part of the uncertainty of the energy performance checking process.

1.5. Structure

This works is structured with an introduction containing the motivations, a description of the found problems which encourage our research, all with the technical context that finally conclude in the contribution. A deep description of the state of the art follows. An analysis of all the information and a proposing of a model described as a step by step process, will be applied into a particular building in the use case section. Finally we will explain as a conclusion the achievements, lessons learned and the future work.

2. STATE OF THE ART

In this section we expose a collection of references and sorted literature related to our topic, split in three categories. The ones related to energy efficiency strategies and management, the ones related to location based factors and technologies, and finally the ones related to the way of structuring these data semantically, focused on Linked Open Data initiatives.

2.1. Energy efficiency strategies

This category of commented literature focuses on different initiatives and strategies for actually reduce consumption and environmental pollution due to the activities performed in buildings. We will see active and passive measures contributing to this task and existing software and tools managing and checking them.

2.1.1. Initiatives, directives and laws

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts (Watson et al., 1996).

Focused on building contribution to climate change, European Union has developed and approved several guidelines and Directives, such as Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002, aiming to reduce consumption in this context, by introducing the concept of energy performance of the building, that should be calculated on the basis of a methodology, which may be differentiated at regional level, and includes, in addition to thermal insulation, other factors that play an increasingly important role such as heating and air-conditioning installations, application of renewable energy sources and design of the building (COM 2002/91/EC).

In Spain, this calculation is defined by Real Decreto 47/2007 (RD 47/2007), concreted in the development of the Building Technical Code (CTE) and its Basic Documents (DB-HE) about energy savings and energy demand limitation as passive measures, and renewable energy sources and energy performance of the building installations as active measures (CTE-DB-HE). The conjunction of these concepts leads to an energy classification scale (IDAE, 2009-1), from A to G, depending on the best to worst building global performance, which is based on some performance indicators related to energy consumption and location-based factors.

In order to support energy performance calculation and improvement, catalogues and manuals are published by both public and private sectors, like the Catalogue of Building systems (http://www.elementosconstructivos.codigotecnico.org/Pages/BusquedaSC.aspx), which contains a wide range of materials, products and building components for roofs, walls, openings and interior partitions with their hygrothermal and acoustic characteristics related to the requirements listed above, and published under the supervision of the Housing Ministry of the Spanish Government.

We can also find a guide like (ITC, 2009), aiming to collect energy measures that can be taken to reduce energy consumption, use it in a more efficient way and promote the use of renewable energies with subsequent reduced environmental impact. Also the specific quality profile of energy savings and sustainability guide (IVE, 2009) develops requirements related to the habits of "Energy Saver", distinguishing quality beyond the minimum requirements established by the Technical Building Code (CTE) and the "Sustainable use of natural resources", whose main objective is to reduce environmental pressures of each stage of the life cycle of resources, including extraction, use and final disposal. Both are developed by Valencia Regional Government initiatives.

Based on CTE-DB-HE4, is mandatory in Spain the use of solar energy for thermal uses, as hot water supply. Private initiatives working on this field are providing technical guides to better take into account location factors like average annual solar radiation, and building characteristics like number of bedrooms, to help accurate calculation of these installations, like Gas Natural has done in (Gas Natural, 2007).

2.1.2. Passive and active technologies

The energy analysis is concerned with predicting the usage profile and cost of energy consumption within buildings. Conceptual design phase of energy modelling will provide the design team with feedback about the impact of various building configurations on its energy performance. A range of possible measures to implement in our building is shown in these documents: better insulation systems, efficient installations and devices, re-usage of resources and renewable energy sources usage are listed inside the documents mentioned above. All of them deal with data.

The designer has to make assumptions for a wide range of input data if information is not yet available on clime, soil and building characteristics, including building geometry, and configuration of spaces, orientation, thermal properties of all construction elements (walls, floors, roofs/ceilings, windows, doors, and shading devices), usage and functional use, internal loads and schedules for lighting, occupants and equipment; heating, ventilating, and air conditioning (HVAC) system type and operating characteristics, weather data, and so on. Moreover, designer has to deal with interoperability problems. That is why some initiatives like BuildingSMART alliance (bSa) and the Open Geospatial Consortium, Inc. (OGC) are developing a test bed for integrating all building data in order to assist decision making along the building lifetime and build a real Building Information Modelling (BIM) system (OGC 10-003r1).

The complexity of these systems and the data needed requires us to take into account only a set of measures dealing with more simple data, balanced with the utility of the results that they can provide.

As described in (Singh et al. 2009), vernacular architecture based on bioclimatic concepts has been developed and used through the centuries by many civilizations across the world. Their own architectural styles based on the local conditions, including different solar passive features related to temperature control and natural ventilation and the use of locally available materials represent a sustainable way of building design.

Reuse of domestic greywater and rainwater has an important role to play in water savings inside buildings. Building occupancy, roof area, appliances type and storage volume affect water saving efficiency. For example, with less than 50 liters of rainwater storage, water reuse can save up to 80% WC flush (Dixon et al. 1999).

The generation of solar electricity from photovoltaics (PV) is beginning to penetrate the energy market in those countries where clear and stable policy commitments have been made. One of the four factors determining the economic performance of the PV system is the solar energy arriving at the surface of the Earth. The annual total of electricity generated from a PV system is calculated using the unit peak power (assumed to be 1kWp in this calculation), the system performance ratio and the yearly sum of global irradiation on a horizontal, vertical or inclined plane of the PV module. On average, covering 0.6% of the EU25+5 territories by PV modules would theoretically satisfy its electricity consumption (Suri et al. 2007).

For the estimation of solar potential for water heating, a model for evaluation procedure consisting of three steps is described in (Voivontas et al. 1998). Among the data needed, there is the solar radiation and the energy demand for water heating, which depends on the number of persons using the building.

The two main barriers to large-scale implementation of wind power are the perceived intermittency of winds, and the difficulty in identifying good wind locations, especially in developing countries (Archer and Jacobson,), but when calculating its potential, wind power reveals as an important source of energy for building whenever they are sited, and tools like (http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy) provide us an approximate result based on data such as wind speed at 50 meters of height, environment (city centre, village, forest, rough terrain…), diameter of rotor and hub height.

The geothermal resources of most European countries have been estimated and compiled in the Atlas of Geothermal Resources in Europe (Hurtera and Schellschmidt, 2003). In order to quantify these resources, they have defined the amount of heat available in the rock (geothermal reservoir) and the characteristics of the reservoir with respect to the extraction of this heat. Geothermal energy can be exploited with various technologies and it feeds a great diversity of applications, alone or in combination with other sources of energy. Although these Atlas exist, we are not taking into account the geothermal resources due to the big differences existing within different technologies and the complexity of data needed, not easily available locally.

2.1.3. Energy software and tools

Once we have deal with strategies and data needed to foresee their results, we need tools to operate these data and calculate results.

In Spain, we are provided by the Government with two free calculation tools for accomplishing both CTE and Real Decreto 47/2007. Both Lider (IDAE, 2009-2) and Calener (IDAE, 2009-3) deal with the energy demand limitation and the energy performance respectively, and need a huge amount of input data not available in the early steps of the design.

Other tools are available in a more or less open and free way. One of the most popular is DOE-2 and its evolution eQUEST. DOE-2 is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building and systems provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills (http://doe2.com/). eQUEST (http://doe2.com/download/equest/eQUESTv3-Overview.pdf) is designed to be run by non expert users by combining schematic and design development building creation wizards, an energy efficiency measure wizards and a graphical results display module with a complete up-to-date DOE-2 building energy use simulation program. Still they need a huge amount of input data not available in the early steps of the design.

Green Building Studio (Autodesk,) is an innovative building energy and carbon analysis web-based service, where data is collect from three sources: a Revit software model (http://usa.autodesk.com/revit-architecture/), the responses to a few basic questions provided by the user, such as building type, location or nearest weather station, and regionalized databases with information about local weather conditions or construction materials. This is a complete tool not suitable for an early stage of design decision making, since a Revit model is a quite complex building information model format with a huge amount of data not available in the early steps of the design. Moreover, both GreenBuildind Studio and Revit are not freeware tools.

The use of multiple programs requires repetitive descriptions of the building and its context in different formats, which makes the use of such programs even more costly and unattractive. Trying to overcome this problem, some developers are trying to design tools that integrate multiple simulation tools and databases, and make their output available in forms that support multicriteria judgment (Papamichael, 1999).The main objective of the Building Design Advisor (BDA) project is to develop a computer-based tool that allows building decision-makers to quickly and easily integrate energy considerations into decision-making, from the early phases of building design (Papamichael et al., 1999) (http://gaia.lbl.gov/BDA/bda3help.pdf). As integration tool is a very interesting initiative, but still too many data not affordable for amateurs and early stages of design are needed.

In the context of RES, a popular tool is found in the RETScreen initiative (RETScreen, 2005).The RETScreen International Clean Energy Project Analysis Software is the leading tool specifically aimed at facilitating pre-feasibility and feasibility analysis of clean energy technologies. The core of the tool consists of standardized and integrated project analysis software which can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of proposed energy efficient and renewable energy technologies. Covering a huge amount of RES technologies, each of them is run in a different Excel sheet, where you need to specify the parameters describing the location of the energy project, the type of system used in the base case, the technology for the proposed case, the loads (where applicable), and the renewable energy resource in detail.

PVGIS is an online tool to calculate potential photovoltaic power supply by location, area available and technology to use (Suri et al. 2007), very useful for its purpose, but not for any other performance interest, like the wind power calculator from (http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy).

In this context, based on the energy demand limitation, energy performance and renewable energy sources constraints, we have seen a wide range of software and methodologies developed, but, as exposed on the introduction section, not all of them serve to same purposes or cover all process, needing complex and different input data in content and format.

2.2. The location factor

Energy efficiency technologies, as we have seen in the previous section, are related to different parameters. Among them, we always find a reference to the place where they are being implemented. This reference may be a mean temperature on the air, under the ground, or even a conventional parameter fixed by a regional law. This section briefly reviews some of these factors depending on the place where we are working in each situation, and being the core of the model to design in next sections.

2.2.1. Physical and political factors

World has been divided along history in different administrative regions as a social and political agreement to facilitate grouping and living conventions. These regions are ruled different one from each other depending on their idiosyncrasy, but most of the times, according to their neighbors, too. In the scope of energy efficiency, we find a pyramidal agreement for setting constrains fitting all regions in the world, since we are treating a worldwide issue.

From international meetings as United Nations Framework Convention on Climate Change, in Kyoto, 1992, or the setting of the IPCC (Watson et al., 1996), definitions have been developed and specified in each different region. Europe has promote its European directive on energy performance (COM 2002/91/EC) and Spain has develop it with its RD 47/2007, whose spirit fits with the international ideas, but its concretizations is based on regional particularities.

This way, we find location-based parameters to accomplish, not because of the nature of our location, but because of the laws that rule our location. This is the case of solar energy for thermal use, which, in Spain, must cover at least a 30% (and up to 70%) of total hot water use of the building, or the photovoltaic installation of at least 6'25kWp, which is mandatory for non residential buildings over a certain area (CTE-DB-HE).

In most cases, including previous ones, natural conditions of location rule the efficiency of the measures to implement. Both technologies and laws ruling its installation take into account the natural environment of the place where they are being installed.

We can find in (IDAE, 2009-2) many of these location-based parameters taken into account for the calculation of the energy demand limitation: latitude, altitude, hours of sun or mean temperatures are involved in the determination of the twelve climatic zones that fix the limit values for thermal transmittance.

Topography and physical environment is very important for shadow calculating in order to determine the efficiency of solar energy, and humidity values are taken into account for condensation limits (CTE-DB-HE).

Other environmental data are regularly used, like annual rain values, used to calculate rainwater storage to reuse in (Dixon et al. 1999); wind speed and temperatures values at different heights, used in (http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy) in order to determine the potential power from wind turbines or in (Archer and Jacobson,) to evaluate global wind power potential.

2.2.2. GIS and SDI

As seen, many environmental data are used to determine energy consumption, performance and efficiency. Users of energy simulation programs often have a wide variety of data from which to choose—from locally recorded, measured data or typical data sets.

Related to weather data, the National Weather Service (NWS) collects weather information from 4.000 stations around the world. The National Renewable Energy Laboratory (NREL) collects, parses, and stores this weather data in a local database to give researchers easy access to the data. The data are available to anyone via Internet and e-mail (Long, 2004).

In general, having data with very different ways to get and work on, we could ask: does it really matter which weather data you use (Crawley and Huang, 1997)? Using a prototype building, the influence of locally measured weather data and typical weather datasets on annual energy consumption, demand, and costs were compared and seen that the range of energy consumption due to actual weather variation can be significant—as much as +7.0%/-11.0% from long-term average weather patterns.

In this context, Geospatial Information Systems (GIS) have started to succeed as a capital technology to store and exploit energy related data, since most of the processes related to the energy performance of buildings involve location-based information.

PVGIS considers and stores in a GIS database (Suri and Hofierka, 2004) monthly averages and yearly average of climatic parameters such as daily global irradiation, ratio of diffuse to global irradiation and clear-sky index (characterizes cloudiness of the sky). It also incorporates DEM data, for the detailed structure of the terrain features (elevation and shadowing) to be represented and properly calculate solar electricity potential (Suri et al. 2007).

Solar radiation and sunshine duration are taken into account in (Voivontas et al. 1998) for determining the solar potential for water heating, being such important location-based parameters to be stored as a GIS database to explore and exploit.

The need of similar geographic information for many different processes and calculations, like mean temperatures for estimating climate zones for thermal transmittance limits, solar water heating or photovoltaic power, leads to the idea of having a real Spatial Data Infrastructures (SDIs) incorporating this kind of environmental data to support research in energy efficiency field, avoiding wasteful duplication of effort and promoting effective and economical management of resources (Clinton, 1994).

In this context we find in Spanish area the IDEE (Spatial Data Infrastructure of Spain), (http://www.idee.es/clientesIGN/wmsGenericClient/index.html?lang=ES) or in the Valencia Region (http://terrasit.gva.es/es/ver) a web service based data provider with cadastral information, land use, biodiversity, statistics, and so on.

Other non official data providers use geospatial information tools like Esri Geoportal Server, a free, open source product that enables discovery and use of geospatial resources including datasets, rasters, and Web services (http://www.esri.com/software/arcgis/geoportal/index.html); GoogleMaps API Web Services, a collection of HTTP interfaces to Google services providing geographic data for your maps applications (http://code.google.com/intl/en/apis/maps/documentation/webservices/index.html); or OpenLayers, developed to further the use of geographic information of all kinds (http://www.openlayers.org/).

2.3. Linked Open Data

The realization of this SDI of environmental data, and, in addition, other data related to energy analysis as building modelling data or energy efficiency data will be very interesting if done in a way that adds a semantic relation between concepts. Linked Open Data initiative matches this approach. In this section we see a background on the semantic relationships and LOD platforms.

2.3.1. From ontologies to the Web of Things

Currently computers are changing from single isolated devices to entry points into a worldwide network of information exchange called the World Wide Web (WWW). Therefore, support in the exchange of data, information and knowledge is becoming the key issue in current computer technology. Ontologies provide a shared and common understanding of a domain that can be communicated between people and application systems. Therefore, they may play a major role in supporting information exchange processes in various areas (Fensel, 2001). We will see the utility of ontologies and the semantic linkage of data to architectural and energy analysis domain on the literature mentioned below.

Design of architectural environments has to take into account various sources of heterogeneous information. Modularity allows a flexible integration of various sources while keeping their thematically different aspects apart. Modular ontologies can reflect and be applied for the domain of architectural design (Hois et al., 2009).

Context-aware computing is about gathering user information and their environment such as user location and preferences, service status, and nearby devices. Such context information is used to adjust environment settings to suit user needs and preferences. As environments can change rapidly, applications must be aware of it and adapt their behavior in real time. Contextual ontology is a key component to enable context sharing and representation (Machuca et al., 2005).

These two previous concepts are interesting for an integrated building design process, involving studies of the energy-related impacts and interactions of all building components, like building location, envelope (walls, windows, doors, and roof), heating, ventilation and air conditioning (HVAC) system, lighting, controls, and equipment, which shows why it is so difficult to find the correlation between different systems. Moreover, using data mining technology can help project teams discover important patterns to improve the building design and is useful to extract interrelationships and patterns of interest from a large dataset (Kim et al., 2010).

An approach to "smart building" services relying on the Web and on Semantic Web formalisms and methods is shown in (Bry et al., 2005) where the modelling of knowledge is realized in different ontologies called "Micro-Theories", written in OWL (the most recent development in standard ontology languages from the World Wide Web Consortium (W3C) (Horridge, 2011) and used to describe domain specific knowledge, e.g., the furniture of a building. Such ontologies are integrated into one "Upper Ontology" specifying common sense knowledge such as the ways of using the furniture.

The term Linked Data refers to a set of best practices for publishing and connecting structured data on the Web. These best practices have been adopted by an increasing number of data providers, leading to the creation of a global data space containing billions of assertions, the so called Web of Data. This Web of Data enables new types of applications operating on top of an unbound, global data space. This enables them to deliver more complete answers as new data sources appear on the Web (Bizer et al., 2009).

Technically, Linked Data refers to data published on the Web in such a way that it is machine-readable, its meaning is explicitly defined, it is linked to other external data sets, and can in turn be linked to from external data sets. (http://www.w3.org/DesignIssues/) outlines a set of 'rules' for publishing data on the Web in a way that all published data becomes part of a single global data space: 1) Use URIs as names for things, 2) Use HTTP URIs so that people can look up those names, 3) When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL), and 4) Include links to other URIs, so that they can discover more things (Bizer et al., 2009).

In this context, the Resource Description Framework (RDF) is a general-purpose language for representing information in the Web. We use its classes and properties to define our resources and relations between them (http://www.w3.org/TR/rdf-schema/).

The basic assumption behind Linked Data is that the value and usefulness of data increases as it is interlinked with other data. In summary, Linked Data is simply about using the Web to create typed links between data from different sources. The basic objectives of Linked Data are to use the RDF data model to publish structured data on the Web, and to use RDF links to interlink data from different data sources. The glue of the data web is RDF links. An RDF link simply states that one piece of data has some kind of relationship to another piece of data (Bizer et al., 2007).

(Bizer et al., 2007) provides practical advice on how to name resources with URI references; discusses terms from well-known vocabularies and data sources which should be reused to represent information; explains what information should be included into RDF descriptions that are published on the Web; gives practical advice on how to generate RDF links between data from different data sources and presents several complete recipes for publishing different types of information as Linked Data on the Web using existing Linked Data publishing tools.

Finally, as more and more devices are getting connected to the Internet, the next logical step is to use the World Wide Web and its associated technologies as a platform for smart things. In the Web of Things concept, smart things and their services are fully integrated in the Web by reusing and adapting technologies and patterns commonly used for traditional Web content. The services that smart things expose on the Web can be supplemented with semantic information, so that smart things can not only communicate on the Web, but also provide a user-friendly representation of themselves. This makes it possible to interact with them via web browsers and explore the world of smart things with its many relationships (Guinard et al. 2010).

2.3.2. Modelling buildings and environment

Some efforts are done in the scope of energy efficiency and building modelling to structure data related, from simple structures to semantically improved datasets, ontologies and Linked Data initiatives.

In recent years, most virtual 3D city models have been defined as purely graphical or geometrical models, neglecting the semantic and topological aspects. CityGML is a common semantic information model for the representation of 3D urban objects that can be shared over different applications, defining classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantic and appearance properties (SIG 3D, 2006).

Building Information Modelling (BIM) is the latest generation of Object Oriented Computer Aided Design systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. But, among other problems, it is found that managing "what if" scenarios for engineering design using a single BIM model for building performance modelling (i.e. energy analysis, sun/shade studies, egress simulation, etc.) does not provide the flexibility needed (Howell and Batcheler, 2005).

Traditional approaches to share project information via file exchange using formats such as .dxf, .dwf, .dwg and .pdf do not transfer the appropriate levels of object intelligence from one model to another. New approaches addressing the need to exchange more intelligent project data include IFC-based model exchange, and the ubiquity of XML as a protocol for transferring sub-sets or "packets" of relevant project information is a key opportunity to achieving interoperability across such a large and fragmented industry (Howell and Batcheler, 2005). The Industry Foundation Classes (IFC) specification is a neutral data format to describe, exchange and share information typically used within the building and facility management industry sector. IFC is the international standard for openBIM and is registered with the International Standardization Organization ISO (http://www.buildingsmart-tech.org/ifc/IFC2x3/TC1/html/ifcproductextension/lexical/).

FIDE data model has established a common reference framework in the Spanish construction sector. It has been developed taking into account IFC standard, and for this reason, its scope is not only national but also international (Garrido and Martinez, 2006). The Spanish Catalogue of constructive systems is available in this format (http://www.elementosconstructivos.codigotecnico.org/Pages/BusquedaSC.aspx).

CityGML (representing a wide range of 3D urban objects) and IFC (representing a very detailed semantic model for buildings) are considered the most prominent semantic models in GIS and BIM, respectively. But both IFC and CityGML use different terminologies to describe the same domain and present a great heterogeneity in their semantics. A semantic model has been proposed by building an intermediate Unified Building Modeled (UBM) to allow bidirectional conversion between them and contribute towards a design of modelling that can support applications on both domains (El-Mekawy and Östman, 2010).

The BIM has been applied to control the space objects and manage the information resources. Ontologies can be the answer to identify the properties of objects and descript their logics (Lee at al., 2008). Given the diversity of home environment, appliances, and residents, the applications for smart homes must be configurable and adaptive. Instead of programming each household, an ontology-based framework will facilitate the automatic composition of appropriate applications (Xu et al., 2009).

DogOnt (Bonino and Corno, 2008) is a house modelling ontology designed to fit real world domotic system capabilities and to support interoperation between currently available and future solutions. DogOnt is composed of two elements: the DogOnt ontology, expressed in OWL, which formalize all the aspects of the domotics and the building, and the DogOnt rules, which ease the modelling process by automatically generating proper states and functionalities for domotic devices, and by automatically associating them to the corresponding device instances through semantic relationships.

An ontology-based model of the TSH (Telehealth Smart Home) is designed in a modularized approach and implemented in OWL. The main goal is to take advantage of the potential of ontologies to describe the domain, in order to provide an effective base for the development, the configuration and the execution of software applications (Lafti et al., 2007).

We find also an OWL encoded context ontology (CONON) for modelling context in pervasive computing environments, and for supporting logic based context reasoning. CONON provides an upper context ontology that captures general concepts about basic context, and also provides extensibility for adding domain-specific ontology in a hierarchical manner (Wang et al., 2004).

In the scope of environmental data, we find also some ontology-based initiatives to manage information.

The aim of the AEMET ontology network is to represent knowledge related to measurements made by the network of meteorological stations of the Spanish Meteorological Agency. Each of these measurements represents the state of the atmosphere (humidity, pressure, temperature, wind, etc.) in a particular place and time. AEMET ontology network follows a modular structure consisting of a central ontology that links together a set of ontologies that describe different sub domains involved in the modelling of the meteorological measurements. These sub domains are: Measurements (weather), Sensors, Time and Location (http://aemet.linkeddata.es/index.html).

GeoLinked Data is an open application that makes use of several heterogeneous Spanish public datasets that are related to administrative, hydrographic, and statistical domains. This application aims at analyzing existing relations between the Spanish coastal area and different statistical variables such as unemployment, population, dwelling, industry, and building trade, dealing with the geometrical information of features (de Leon et al., 2010).

In a less concrete domain, we find general, big, helpful ontologies for modelling context and environment, like the OWL Web Ontologoy Language, a language for defining and instantiating Web ontologies. An OWL ontology may include descriptions of classes, properties and their instances (http://www.w3.org/ TR/2004/REC-owl-guide-20040210/).

Basic Geo (WGS84 lat/long) Vocabulary is a basic RDF vocabulary that provides the Semantic Web community with a namespace for representing lat(itude), long(itude) and other information about spatially-located things, using WGS84 as a reference datum (http://www.w3.org/2003/01/geo/wgs84_pos#), OWL-Time ontology provides a vocabulary for expressing facts about topological relations among instants and intervals, together with information about durations, and about datetime information (http://www.w3.org/TR/owl-time/) and TISC, the Open Time and Space Core Vocabulary, is a lightweight spatiotemporal vocabulary aiming to provide spatial and temporal terms to enable practitioners to relate their data to time and space (http://observedchange.com/tisc/ns/).

Dublin Core Metadata Initiative (http://dublincore.org/documents/dcmi-terms/) maintains some metadata terms related to the author, classification and structure of all kinds of information and FOAF is a project devoted to linking people and information using the Web, regardless of where information is. FOAF integrates three kinds of network: social networks of human collaboration; representational networks, and information networks that use Web-based linking to share independently published descriptions of this inter-connected world (http://xmlns.com/foaf/spec/).

DBpedia is a community effort to extract structured information from Wikipedia and to make this information available on the Web. The DBpedia knowledge base is served as Linked Data on the Web, being one of the central interlinking-hubs of the emerging Web of Data (http://wiki.dbpedia.org/About).

2.3.3. Tools

Protégé is a widely used open-source ontology and knowledge base editor. While ontologies are becoming so large in their coverage that no single person or a small group of people can develop them effectively and ontology development becomes a community-based enterprise, the Web becomes the natural platform of choice for developing ontologies collaboratively. Web-Protégé is a web-based lightweight ontology editor, open source, providing an augment ontology-editing environment with facilities for discussions and annotations (Tudorache et al., 2009).

The quantity of linked data is growing rapidly. These data include ontologies, governmental data, statistics and so on. The task of obtaining the data from various sources, integrating and fine-tuning the data for desired analysis, needs a good model with efficient user interface design to perform the Linked Data Mining (Narasimha et al., 2011). As sets of Linked Open Data are provided and available, tools for manage them are appearing and showing the visual power of the Data Web (http://www. visualdataweb.org/tools.php).

A web of linked RDF data may be enabled by standards specifying how links should be made in RDF and under what conditions they should be followed as well as powerful generic RDF browsers that can traverse an open web of RDF resources. Tabulator project is an attempt to demonstrate and utilize the power of linked RDF data with a user-friendly Semantic Web browser that is able to recognize and follow RDF links to other RDF resources based on the user's exploration and analysis (Berners-Lee et al., 2006).

Since RDF is a directed, labeled graph data format for representing information in the Web it can be queried. SPARQL (http://www.w3.org/TR/rdf-sparql-query/) can be used to express these queries and contains capabilities for querying required and optional graph patterns along with their conjunctions and disjunctions. Its results can be results sets or RDF graphs.

RelFinder is an approach for the interactive discovery of relationships between selected elements via the Semantic Web (Heim et al., 2010). It emphasizes the human aspect of relationship discovery by offering sophisticated interaction support. It extracts and visualizes relationships between given objects in RDF data and makes these relationships interactively explorable. The interactive visualization of the graph supports a systematic analysis of the found relationships by providing highlighting, previewing, and filtering features (Heim et al., 2009). The application potentials include assisting business analyst in decision-making.

RDF GRAph VIsualization Tool (RDF Gravity) is a tool for visualizing directed graphs built in RDF and OWL. The tool provides a simple yet powerful visualization of RDF graph structures and the ability to filter out and visualize specific parts or fragments of RDF Graphs (Goyal and Westenthaler,).

LiDDM (Linked Data Data Mining) is a model that helps to effectively interact with linked data present in the web in structured format, retrieve and integrate data from different sources, shape and fine-tune the so formed data for statistical analysis, perform data mining and also visualize the results at the end (Narasimha et al., 2011).

Map4rdf is a mapping and faceted browsing tool for exploring and visualizing RDF datasets enhanced with geometrical Information. Map4rdf is an open source software in which one just need to configure it to use your SPARQL endpoint and provides you with a map-based visualization of your data (http://oegdev.dia.fi.upm.es/projects/map4rdf/).

D2R Server is a tool for publishing non-RDF relational databases as Linked Data on the Web. Using a declarative mapping language, the data publisher defines a mapping between the relational schema of the database and the target RDF vocabulary. Based on the mapping, D2R server publishes a Linked Data view over the database and allows clients to query the database via the SPARQL protocol (Bizer et al., 2009) (Bizer and Cyganiak, 2006).

Virtuoso is a multi-model data server for data management, access, and integration. The hybrid server architecture of Virtuoso enables it to offer traditionally distinct server functionality within a single product that covers the areas of Relational Data Management, RDF Data Management, XML Data Management, Free Text Content Management and Full Text Indexing, Document Web Server, Linked Data Server, Web Application Server and Web Services Deployment (SOAP or REST) (http://virtuoso.openlinksw.com/). Aemet and GeoLinkedData initiatives have used this server.

The Pubby server can be used as an extension to any RDF store that supports SPARQL. Pubby rewrites URI requests into SPARQL queries against the underlying RDF store. Besides RDF, Pubby also provides a simple HTML view over the data store and takes care of handling 303 redirects and content negotiation between the two representations (Bizer et al., 2009) (http://www4.wiwiss.fu-berlin.de/pubby/).

Search engines such as Falcons provide keyword-based search services oriented towards human users, to find linked data. The user is presented with a search box into which they can enter keywords related to the item or topic in which they are interested, and the application returns a list of results that may be relevant to the query. However, rather than simply providing links from search results through to the source documents in which the queried keywords are mentioned, Falcons provides a more detailed interface to the user that exploits the underlying structure of the data (Bizer et al., 2009) (Cheng and Qu, 2009).

R is a language and environment for statistical computing and graphics. R provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering ...) and graphical techniques, and is highly extensible. R is available as Free Software (http://www.r-project.org/about.html). Rrdf is an R package that provides methods to read and write RDF, and query RDF using SPARQL; add properties, triples or prefixes for namespaces; combine and query models… This makes it the optimum tool to implement all operations and formulae needed to operate data from our models and integrate results back (Willighagen, 2011).

3. MODELLING

Since we are addressing to non professional users and early stages of the professional design process, we are not aiming to get a result as accurate as the ones got using previously described tools, covering the whole process and details of the energy performance analysis (IDAE, 2009-2) (IDAE, 2009-3) (http://doe2.com/) (http://doe2.com/download/equest/eQUESTv3-Overview.pdf) (Autodesk) (RETScreen, 2005).

Our goal is to provide an easy to understand energy efficiency strategy (related to constructive system or renewable energy source system) based on some required data: the location and characteristics of the building, for supporting decision making in the very beginning of a project.

Involving non expert users, we assume previous data cannot be complex or inaccessible or difficult to understand, and thus the other goal is to reduce to the maximum this collection of data, necessary and sufficient to get an applicable result.

The design principles considered try to keep simplicity in both data and processes models, reusing existing available data when possible. For doing so, we choose Linked Open Data for several reasons, among them, the fact that LOD is a semantic based open source model, which will facilitate the addition of meaning and structure to the data linkage and its reusability (Bizer et al., 2009).

3.1. Semantic model

All these data extracted, stored and transformed are exposed as LOD where other users could reuse it for this or other purposes. We choose LOD for several reasons, among them, the fact that LOD is a semantic based open source model. This section describes the terms used to model our model as Linked Open Data and the technologies to implement functionality, but it does not implement it.

3.1.1. Linked Open Data vocabularies

To expose our data, we have chosen the Linked Open Data infrastructure, due to its principles of free of charge open source infrastructure for sharing knowledge. As seen in the state of the art, many initiatives are using this infrastructure, both in a general and descriptive context and in a more focused topics related to this work. Thus there are chances to reuse information and data already available.

Being one of the objectives of this work to be accessible for non-expert users, the idea is to re-use the more quantity of data and structures available to reduce to the maximum the data that users have to provide. We develop a model based on available, accessible data, and benefit from the structure and semantics published by other initiatives.

All things described by RDF (http://www.w3.org/TR/rdf-schema/) are called resources, and are instances of the class rdfs:Resource, who in turn is an instance of rdfs:Class. All other classes are subclasses of this rdf:Class. The class rdfs:Literal is the class of literal values such as strings and integers. rdfs:Literal is also an instance of rdfs:Class and a subclass of rdfs:Resource. rdf:Property is the class of RDF properties and is also an instance of rdfs:Class. Instances of rdf:Property used in our model are:

- rdfs:range: the values of a property are instances of some class.
- rdfs:domain: any resource that has a given property is an instance of some class.
- rdf:type: a resource is an instance of a class.
- rdfs:subClassOf: all the instances of one class are instances of another.
- rdfs:subPropertyOf: all resources related by one property are also related by another.
- rdfs:label: to provide a human-readable version of a resource's name.
- rdfs:comment: to provide a human-readable description of a resource.

Every individual in the OWL world (http://www.w3.org/ TR/2004/REC-owl-guide-20040210/) is a member of the class owl:Thing. Thus each user-defined class is implicitly a subclass of owl:Thing. An object property is defined as an instance of the built-in OWL class owl:ObjectProperty. But maybe the most important term from this vocabulary is the property owl:sameAs, which enables connections between different ontologies.

From (http://www.w3.org/2003/01/geo/wgs84_pos#) basic Geo vocabulary, we use:

- geo:lat: The WGS84 latitude of a SpatialThing (decimal degrees).
- geo:long: The WGS84 longitude of a SpatialThing (decimal degrees).
- geo:alt: The WGS84 altitude of a SpatialThing (decimal meters).
- geo:SpatialThing: Anything with spatial extent.

We have re-use OWL-Time ontology (http://www.w3.org/TR/owl-time/) for describe intervals like months or years and re-use some properties and classes from FOAF vocabulary (http://xmlns.com/foaf/spec/):

- foaf:depiction: relationship between a thing and an Image that depicts it.
- foaf:based_near: relates two "spatial things".
- foaf:Image is a sub-class of foaf:Document corresponding to those documents which are images (such as JPEG, PNG, GIF bitmaps, SVG diagrams etc.)

The Dublin Core vocabulary (http://dublincore.org/documents/dcmi-terms/) term isPartOf: a related resource in which the described resource is physically or logically included. But the most important terms from Dublin Core vocabulary are those related to author and publication data, which despite its importance, are not exploited in this work, since we are focusing on the functionality.

TISC vocabulary (http://observedchange.com/tisc/ns/) is useful for describing a building:

- tisc:northOf: an abstract property to express that an object is North of another (same for the rest of cardinalities).
- tisc:nextTo: an abstract property to express that an object is next to another.
- tisc:locatedAt: an abstract property to express that an object is located at somewhere.
- tisc:areasize: an abstract property to express the size of the area of an object.
- tisc:hasWidth: an abstract property to express that an object has certain width.
- tisc:happensAt: a predicate to state when something happens

We have used some of DBpedia concepts and properties (http://wiki.dbpedia.org/About):

- dbpp:buildingType: an rdf property defining the building type.
- dbpprop:use: an rdf property defining the use of something.
- dbpprop:orientation: an rdf property defining the orientation of something.

For locating cities and places, we use both the Geonames geographical database from all over the world (http://www.geonames.org/) and the GeoLinked Data (.es) open initiative (http://geo.linkeddata.es/web/guest/home) to enrich the Web of Data with Spanish geospatial data. In this case we see the value of owl:sameAs property.

AemetLinked Data (.es) is an open initiative publishing diverse information sources belonging to the Spanish Meteorological Agency (http://aemet.linkeddata.es/ index_en.html). We re-use this effort to describe weather data for the needs of our model:

- aemetonto:observedInInterval:
- ssn:observedProperty:
- aemetonto:valueOfObservedData:
- aemetonto:stationName:
- aemetonto:WeatherStation:

	classes	**properties**
owl:	owl:Thing, owl:ObjectProperty	owl:sameAs
rdf:	rdfs:Class, rdfs:Resource, rdfs:Literal, rdfs:Property	rdfs:range, rdfs:domain, rdf:type, rdfs:subClassOf, rdfs:subPropertyOf, rdfs:label, rdfs:comment
geo:	geo:SpatialThing	geo:lat, geo:long, geo:alt
time:	time:Interval	
foaf:	foaf:Image	foaf:depiction, foaf:based_near
dct:		dct:isPartOf
tisc:		northOf (& rest of cardinalities), nextTo, locatedAt, areasize, hasWidth, happensAt
dbpedia:		dbpp:buildingType, dbpprop:use, dbpprop:orientation
aemetonto:	aemetonto:WeatherStation	ssn:observedBy, aemetonto:observedInInterval, ssn:observedProperty, aemetonto:valueOfObservedData, aemetonto:stationName
ifc	ifcBuilding, ifcSpace, ifcBuildingElement, ifcBuildingOpening, ifcWall, ifcWindow, ifcDoor, ifcRoof, ifcSlab	has
citygml	AbstractBuilding, Room, BoundaySurface, Opening, WallSurface, Window, Door, RoofSurface, GroundSurface	boundedBy
fide	Constructive_Element, EHE_Wall, EHE_Pitched_Roff, EHE_Flat_Roof, EHI_Interior_Roof, EVI_Interior_Wall, Material, Isolation	price, transmittance(W/m2K), vapourResistance, width, density(kg/m3), thermalResistance(m2 K/W), specificHeat(J/kg K), thermalConductivity(W/m K), thermalResistance(m2 K/W)

Table 1.- Summary of re-used terms

The Industry Foundation Classes (IFC) specification is a neutral data format to describe exchange and share information typically used within the building and facility management industry sector. IFC is the international standard for openBIM and registered with the International Standardization Organization ISO as ISO16739 (http://www.buildingsmart-tech.org/ifc/IFC2x3/TC1/html/ifcproductextension/lexical/). We have used these definitions to characterize the elements described in our model as building elements and their relations in order to provide a building description which can be extended later for other purposes in a standard way. Based on IFC model, FIDE is a national initiative modelling buildings. The national catalogue of constructive systems uses it, so we have adopted its terms to define constructive systems.

In the other hand, CityGML is a common information model, developed by OGC, for the representation of 3D urban objects. It defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their properties (http://www.citygml.org/index.php?id=1538). We define our building model re-using this vocabulary also, for the same reasons as the IFC model.

In Table 1 we summarize the classes and properties re-used that allow an interlinking between existing resources and new descriptions. This avoids duplicity of terms.

3.1.2. LODBLESS vocabulary

Other classes, resources and properties are specific of this work and have to be defined by ourselves. We rely on previous vocabularies to define new ones.

module	classes	properties
Ene:	BuiEne, EnergyClass	consumption, eleCon(kWh/yr), eleP(€/kWh), eleConP(€/yr), eleConMonth(kWh), gasCon(kWh/yr), gasP(€/kWh), gasConP(€/yr), gasConMonth(kWh), waterCon(m3/yr), waterP(€/m3), waterConP(€/yr), waterConMonth(m3), res, resPVInv(€), resPVGen, resPVGenMonth, resSTInv(€),energyPerformanceClass, resSTGen, resSTGenMonth, resWPInv(€), resWPGen, resWPGenMonth, resWSInv(€), resWStore, resWStoreMonth
Bui:		hasNeighbor, hasOpening, hasSystem, function, limitKForWalls, limitKForFloors, limitKForRoofs, limitKForWindowsN, limitKForWindowsEW, limitKForWindowsS, limitKForWindowsSESW, limitFForRoofWindows, limitFForWindowsN, limitFForWindowsEW, limitFForWindowsS, limitFForWindowsSESW,
Loc:	BuiLoc, ClimaticZone,	weatherStation, database, gdMonth, radMonth, irradiation, climaticZone, windSpeedAverage, windDir, rainwater, rainWaterMonth
Sys:	RESSystem	complexity, efficiency

Table 2.- Summary of new terms

First thing we will define different namespaces for four blocks of our model: ene: for the energy efficiency concepts, bui: for the building related concepts, loc: for location concepts and sys: for the systems concepts. Then we create all classes we need and not existing in previous vocabularies, and their properties. In Table 2 we see the new classes and properties that are linked between themselves and re-used resources and descriptions.

The energy module takes into account all concepts related to the energy consumption, classification and generation of a building, not existing in others vocabularies. It is composed of two classes and 31 properties defined with the terms described in the previous section (http://www.anasanhue.hostzi.com/joomla/index.php/en/projects/information-technologies/92-lodblessene).

- ene:BuiEne: an ObjectProperty class collecting all energy data from a building.
- ene:EnergyClass: an ObjectProperty class for the energy performance of a building.
- ene:consumption: a building property attaching it to a BuiEne.
- ene:eleCon: a BuiEne property defining the electricity consumption in kWh/yr as a Literal (also for gas and water – in m3/yr).
- ene:eleP: a BuiEne property defining the electricity price in €/kWh as a Literal (also for gas and water – €/m3).
- ene:eleConP: a BuiEne property defining the electricity consumption in €/yr as a Literal (also for gas and water).
- ene:eleConMonth: a BuiEne property defining the electricity consumption in a month interval in kWh as a Literal (also for gas and water – in m3).
- ene:res: a BuiEne property stating the use of a RES by a building.
- ene:resPVSystem: a BuiEne property stating the RESsystem for PV installation used (also for solar thermal, wind power and water storage installations).
- ene:resPVInv: a BuiEne property defining the investment price of a PV installation in € as a Literal (also for solar thermal, wind power and water storage installations).
- ene:resPVGen: a BuiEne property defining the electricity generated by a PV installation in kWh/yr as a Literal (also for solar thermal, wind power and water storage installations).
- ene:resPVGenMonth: a BuiEne property defining the electricity generated by a PV installation in a month interval in kW as a Literal (also for solar thermal, wind power and water storage installations).
- ene:energyPerformanceClass: a building property attaching it to a EnergyClass.

The building module includes all concepts related to the building organization and composition, not existing in others vocabularies. It is composed of 16 properties defined with the terms described in the previous section.

- bui:hasNeighbor: a ifcSpace or Room property stating its ifcSpace or Room neighbor.
- bui:hasOpening: a ifcBuildingElement or BuondarySurface property stating its ifcBuildingOpening or Opening.
- bui:hasSystem: a ifcSpace or Room, ifcBuildingElement or BuondarySurface, or ifcBuildingOpening or Opening property stating its Constructive_Element.
- bui:limitKForWalls: a ifcWall or WallSurface property defining its limit transmittance value as a Literal (also for the rest of functions).
- bui:function: a ifcBuildingElement or BuondarySurface, or ifcBuildingOpening or Opening property stating if they are ifcWall, ifcRoof, ifcSlab, ifcWindow or ifcDoor or WallSurface, RoofSurface, GroundSurface, Window or Door.
- bui:limitFForWindowsSESW: a ifcWindow or Window with SE or SW orientation property defining its limit solar factor value as a Literal (also for Doors and other orientations).

The location module takes into account all concepts related to the location characteristics and parameters present around the building, mostly weather and climate observations, not existing in others vocabularies. It is composed of two classes and 10 properties defined with the terms described in the previous section.

- loc:BuiLoc: an ObjectProperty class collecting all location data from a building.
- loc:ClimaticZone: an ObjectProperty class defining the climatic zone of a building.
- loc:weatherStation: a BuiLoc property defining its related WeatherStation.
- loc:database: a BuiLoc property defining its related Database.
- loc:gdMonth: a BuiLoc property defining its grades-day in base 20 for a month interval in grades as a Literal.
- loc:radMonth: a BuiLoc property defining its received radiation for a month interval in kWh/m2 as a Literal.
- loc:irradiation: a BuiLoc property for received radiation in kWh/m2yr as a Literal.
- loc:climaticZone: a BuiLoc property stating its ClimaticZone.
- loc:windSpeedAverage: a BuiLoc property defining wind speed in m/s as a Literal.

- loc:windDir: a BuiLoc property defining its dominant wind direction as a Literal.
- loc:rainwater: a BuiLoc property defining received rain in m3/m2yr as a Literal.
- loc:rainWaterMonth: a BuiLoc property defining its received rain water in a month interval in m3/m2 as a Literal.

The systems module comprises all concepts related to the systems composition and functionality, affecting their efficiency and performance, not existing in others vocabularies. It is composed of one class and two properties defined with the terms described in the previous section.

- sys:RESSystem: a class describing a renewable energy resource system asigned to a ifcSpace or Room by the hasSystem Property.
- sys:complexity: a RESSystem or Constructive_System property defining its mounting complexity (it may be differently defined for each system type) as a Literal.
- sys:efficiency: a RESSystem property defining its performance efficiency.

3.2. Conceptual model

For running this model, first step is discovering and/or accessing data. We need, as seen in previous section, several location-based kinds of data, and, since we can imagine other data useful for other applications, we will try to structure data in a way that our data can be reused for other implementations, just by accessing it and maybe adding some new data into our model.

3.2.1. Location data

The most important data from each location for our project are those related to the terrain on which we are building our building, and the climatic characteristics of its environment.

Soil data, with its types and internal temperatures could be very useful for geothermal installations providing energy to buildings. Nevertheless, in this work, we are not exploiting this field, but those related to energy efficiency strategies related to climatic conditions.

As seen in Figure 1, location (BuiLoc) data are structured as a five steps chain to get the climate parameters needed. Locgeo can be defined as a point, with its coordinates; as a parcel ID, which also has some coordinates, in this case forming a polygon; or as a simple place name, much more uncertain location, but related to a position too.

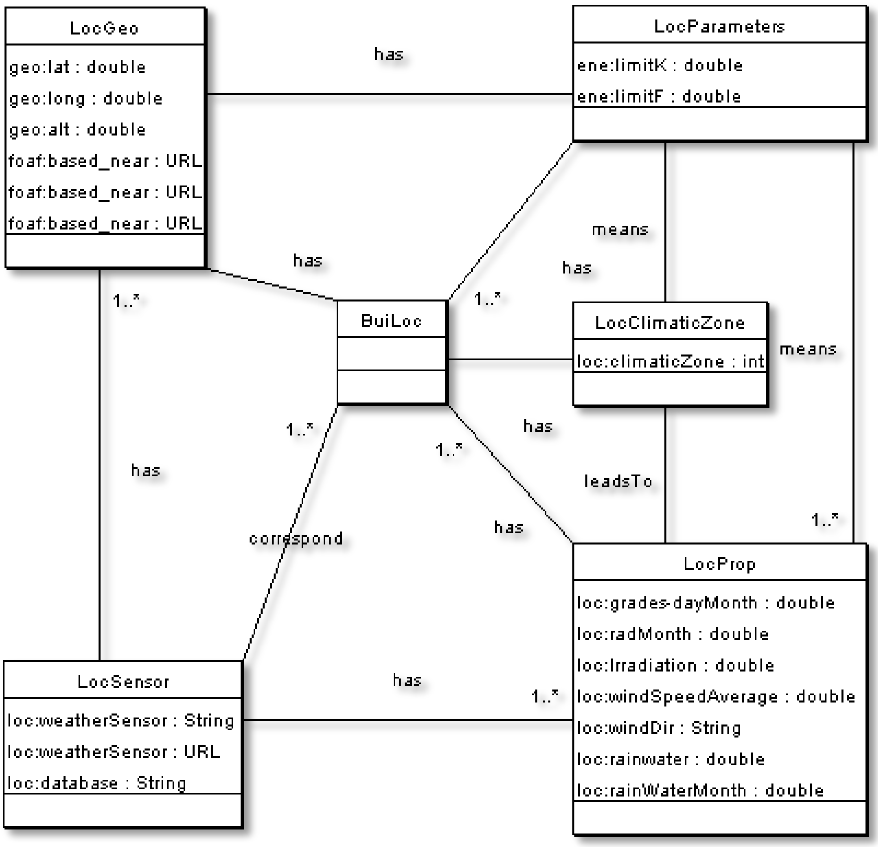

Figure 1.- Climate data

Attached to this location, a sensor (or a set of them) will provide weather data. LocSensor in this model can be one of those installed and defined by Aemet or any other sensor measuring climatic data. Finally, when no sensor is available relatively close to a location, we can use historic data stored in a database.

Sensors will provide data about certain climatic properties. LocProp can be all those defined by Aemet, and also other ones interesting for our research field, that will lead us to classify our location in one of the theoretical zones (LocClimaticZone) that rule some energy efficiency strategies parameters (LocParameters) although other ones are directly got from LocProps. These parameters are then related to the building location.

Climate data are accessible in many places, from official institutions like Aemet, to social networks like Meteoclimatic. Alternative sources are sensor networks deployed by private interests or public institutions like City Halls (Valencia network), and even databases with historical data like INE (Instituto Nacional de Estadística – National Institute for Statistic Studies) databases.

So more and more we can access a range of sensors networks measuring, among other things, meteorological data that can be useful for energy efficiency models, but depending on the source these data are usually provided in very different formats. Aemet (Spanish meteorological agency) data are already available as LOD, but Meteoclimatic network or INE databases need an integration of their data into a semantic model that will add them some meaning and structure. This would provide discovery, accessibility and usability properties to data, transformed this way into more useful information.

3.2.2. Building data

When checking energy performance of a building, we are asked to introduce an important number of very specific data. In this work we are trying to reduce this number of data and its complexity by focusing on the very essential data needed for constrain from the very beginning some characteristics of the building that will improve its energy performance.

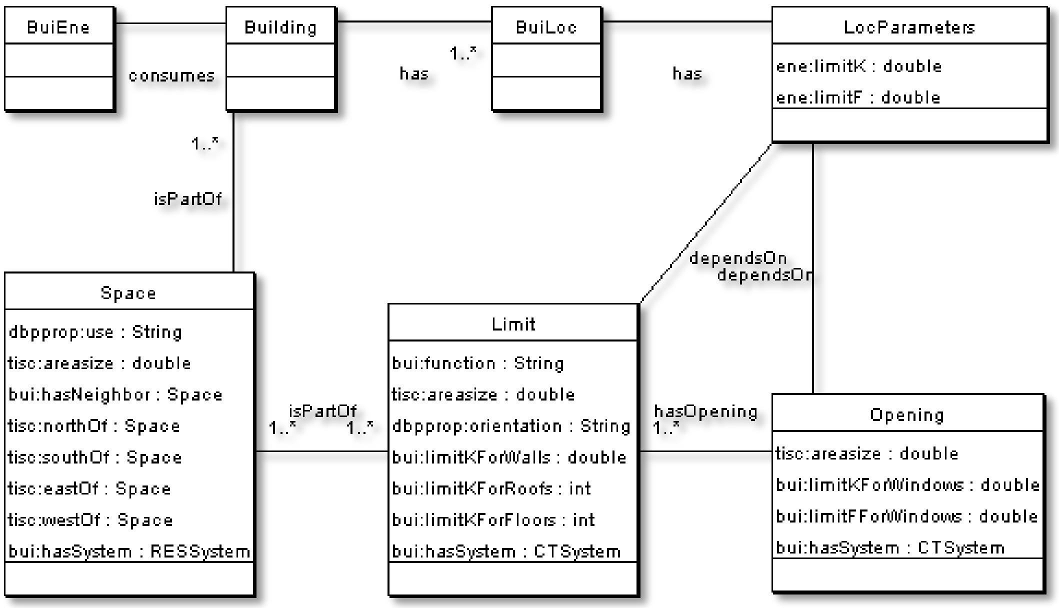

Figure 2.- Building data

As seen in Figure 2, our model of data for buildings will focus on three aspects: first one is its BuiLoc, presented in previous section. Other aspect defining our building is its physical distribution and characteristics. A building will be defined by its spaces, which will have other spaces as neighbors, with, at least, an area, a use for the space - garden, terrace, living room…-, a RES installed, and some limits confining them. Limits are really important and form the building envelope, which protects spaces from environment conditions and limit the energy demand of a building. They are defined by their constructive system, their area, orientation, function – façade, roof, wall…-, and some properties as its thermal transmittance (K), and can have openings, similarly defined.

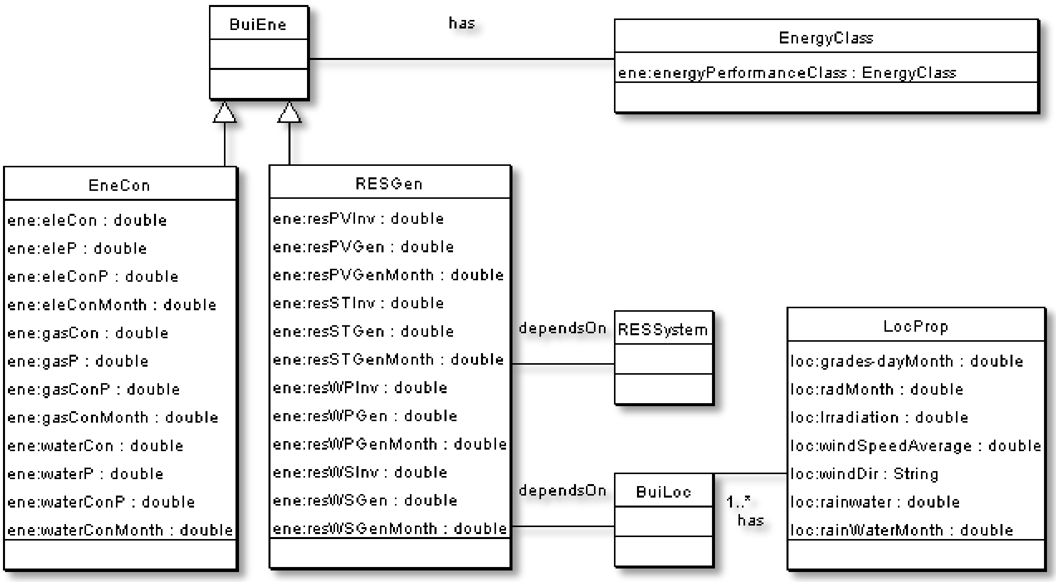

Figure 3.- Energy data

Finally, the third aspect of buildings defined in this model is the energy consumption. It can be estimation or an actual reading of a meter. To estimate energy consumption we need to define the whole set of appliances and installations of the building, which at the beginning of a project is not an easy task, nor is real, since you don't really know if you are finally using these appliances and how. That is why we consider in this model (for the moment) the real energy consumption read from meters. That means that this parameter is only considered for existing building undertaking a refurbishment.

As seen in Figure 3, BuiEne will be usefully classified and defined as consumed from the network and from the RES installed in the building. Energy consumed from renewable energy resources assessment will be explained in the next section as an energy efficiency strategy. Finally from an energy performance certificate or by running the model, we get the energy classification, from A to G.

This data will be added by people wanting to run the model in their buildings. With time, this database will be enough populated to perform on it different studies. To have some meaning and structure, this database will follow our semantic model, which will be exposed as LOD.

3.2.3. Energy efficiency strategies data

In this work we are focusing in energy efficiency strategies useful for the initial states of a building project, helping us to take decisions about our building shape and materiality in a very early stage, before going further in complex descriptions and documents.

These strategies are the materiality of the building envelope, allowing the energy demand limitation, and the renewable energy sources available on site, allowing energy consumption reduction and better energy performance.

Each strategy, called system, is modeled as seen in Figure 4, and it is differentiated between passive (constructive, CTSystem) and active (RESSystem).

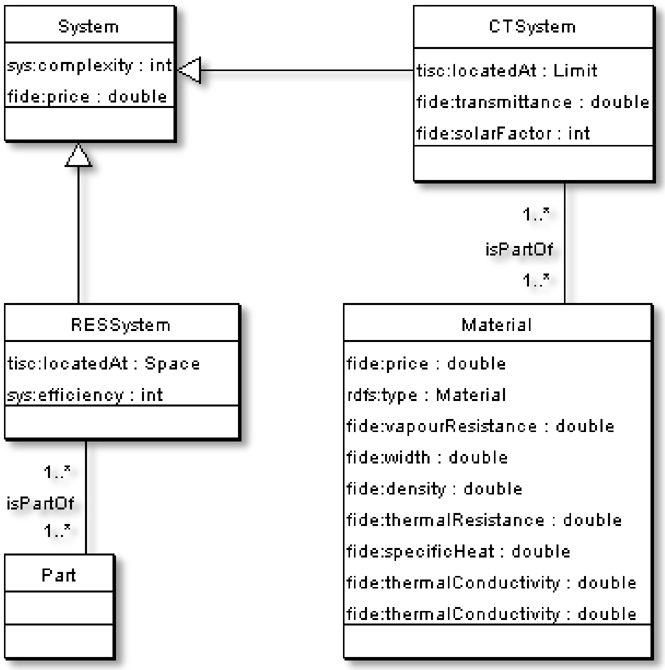

Figure 4.- Systems data

Then data are packed in three groups. First one is location, which, in this case is differently defined then in the other data models, since here, each system will be located in a limit when a constructive system, or a space when a RES system, and from how it is related to the building data and through it, related to climate data. As seen in Figure 3, this relation gives as an output the RES generation potential depending on system used and the building location.

Back in Figure 4, we see how elements composing the systems are defined. A number of elements are described with their different properties as dimensions, capacities, price, energy potential or thermal transmittance, which can be increased at any moment in the future.

Finally we have the properties of the system as a global item, used for choosing the best strategy in each location, with respect to some criteria: price, complexity (number of elements), renewable energy potential or limitation of energy demand are characteristics defined on each system.

Data about the envelope constructive systems is available in different sources, most important of them, from Spanish normative point of view, is the Catalogue of Constructive Elements created by Ministry of Development, where a range of materials are stored with their properties, including functionality and position, facilitating the searching for different constructive systems and its characteristics. This catalogue follows the XML FIDE format, which we will transform into our semantic model to add more meaning and structure and expose it as LOD.

For RES systems data, we need to consult different sources. For solar energy (photovoltaic use) we will use PVGIS initiative data. We will extract information from PVGIS calculator and store it. We will transform these data into our model and expose it as LOD.

We need also to build up a dataset where different RES systems are described for solar energy (thermal use) installations, wind power alternatives and water storage and recycling systems. We are not developing this part during this work, but PV systems will be characterized and structured in an enough simple way to fit all different systems.

3.3. Computational model

The final realization of this work would be a an application, as seen in Figure 5, where different application modules (first layer) apply a set of processes each (second layer).

These processes will access and operate data (third layer) to provide a result. That is, we need to define the relationships and mechanisms between data that will provide new data.

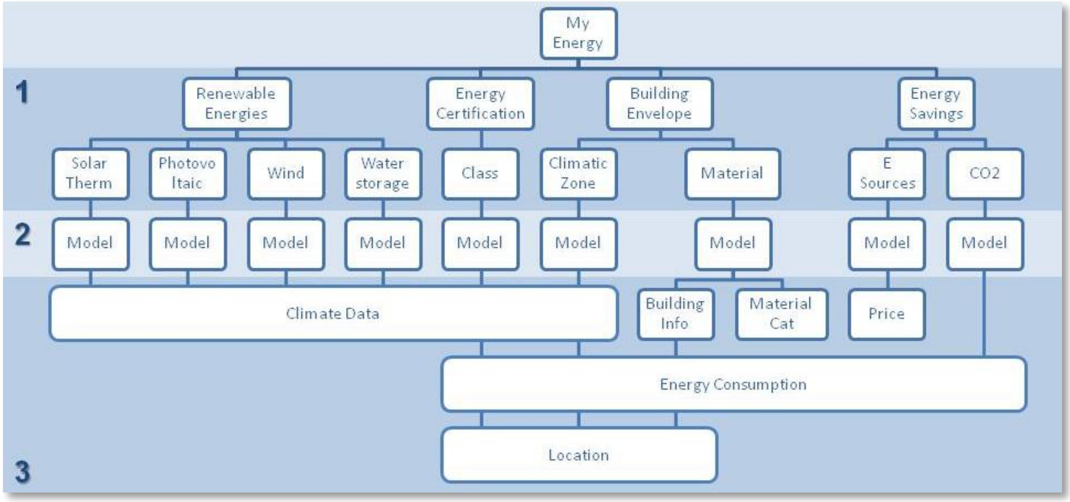

Figure 5.- Application schema

Previous section describes how third layer is modeled and data is classified, structured and stored. This section describes second layer where data stored previously is processed to provide a result and the analysis we can perform on it. For doing so, we first model the analysis processes included in this work, to finally present how they can be implemented.

3.3.1. Processes

In this section, energy demand limitation verification process and energy performance classification process is studied and a simplified step by step process is proposed.

First big analysis performed in this project is related to passive measures that can be implemented in a building for limiting its energy demand. This is a first step to energy savings, since, the less energy you need the less energy you consume. Based on the Energy Demand Limitation process defined in the CTE-DB-HE1, which establishes a top thermal transmittance for each constructive system in the building envelope and the mean value of thermal transmittance for all constructive systems performing same function in same orientation, we can define process shown in Figure 6.

Starting from a location, defined by its coordinates, its parcel or the limit of a city, a “based near” process is applied, using a buffer around the location trying sequential distances until we find the nearest sensor data. In case we find more than one sensor inside the buffer limits, we will calculate the mean of each value, or calculate which one is the nearest. In case we exceed an established distance, we will look for a database with historical data. In case we don't have enough data, we will jump to pre-defined climatic zone value.

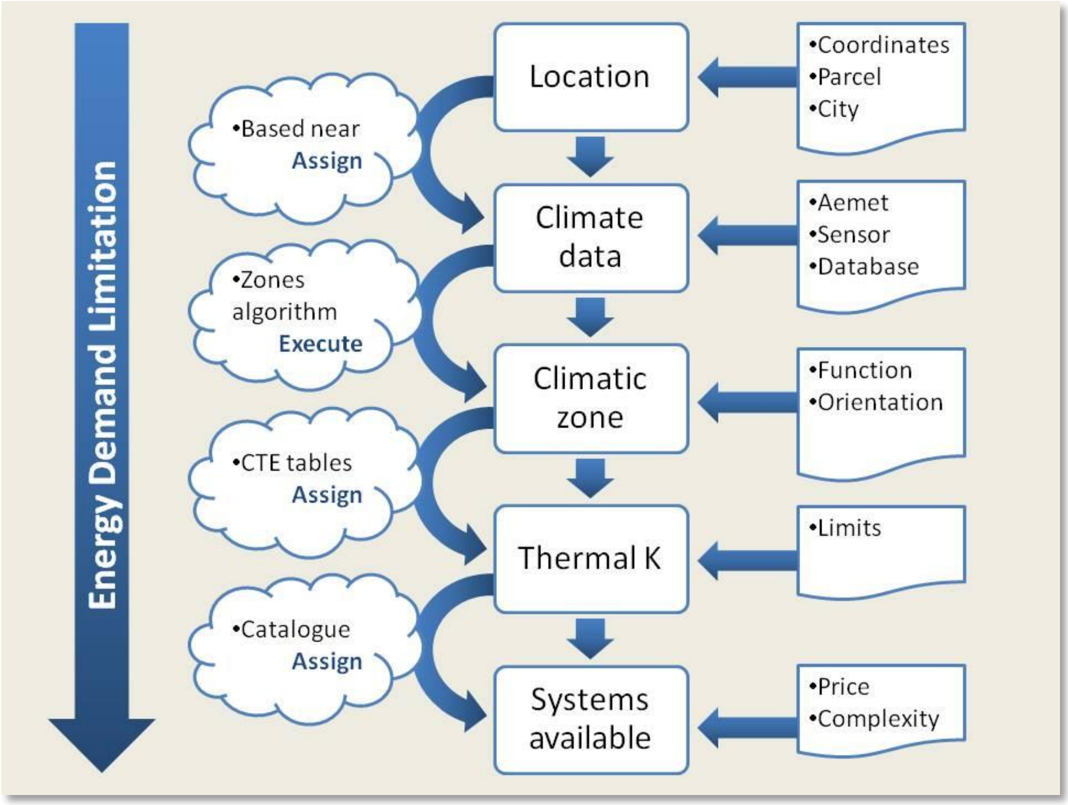

Figure 6.- Process for envelope systems

Once we know which sensor we are using, we get meteorological data needed. Next process will perform the climatic zones algorithm described in CTE-DB-HE1, Annex D, in order to calculate a more accurate correspondent climatic zone. Pre-defined climatic zones are calculated for capital cities, letting other municipalities with different environmental conditions uncalculated and statistically assigned to nearest capital city zone.

With correspondent climatic zone known, we list from building information all functions and orientations existing in the building to, from values defined in tables 2.1 and 2.2 of CTE-DB-HE1, assign them their maximal thermal transmittance.

Next step will be listing each limit of the building and crawl constructive systems catalogue to find all those systems fitting the thermal transmittance constrains. This is possible due to the fact that a) limits have a function which matches systems function and b) limits have a function and orientation which have a thermal transmittance assigned in previous step, and match thermal transmittance of constructive systems.

These lists with constructive systems available for each limit can be long lists, which is why systems have also some parameters to filter results by best thermal transmittance, less complex or cheapest system, that will allow us performing some analysis comparisons in order to choose with different criteria.

Same process is applied for parts of the building envelope defined as gaps or windows, with a difference in the critical property, being here the solar factor, and not the thermal transmittance. Solar factor is tabulated in CTE-DB-HE1 tables classified by orientation and zone like the rest of building envelope systems performing other functions. Solar factor is stored in the catalogue as a property of window systems as well.

Based on the Energy Performance Classification calculation, second process deals with RES available depending on the location, and the best energy performing classification, when energy consumption data are available, as we see in Figure 7.

First steps are the same as those from previous process, to find out correspondent climatic zone from a location, not only by proximity to a tabulated value but trying to take into account real meteorological data to better fit location with climatic zone. In this case, there is a difference in this calculation, as we don't take into account only climatic zones defined by CTE-BD-HE1, but perform different algorithms for specific zones defining wind and solar power potentials, like the ones described in PVGIS for PV calculations.

With this set of climatic zones, we list building spaces and limits accomplishing functions and use compatibles with RES installation, like garden, terrace or roof, with their areas and orientations and perform on them potential power algorithms to know how much power can be installed on them depending on the building climatic zone.

These lists with RES systems available have also some parameters to filter results by most energy potential, less complex or cheapest system, that will allow us performing some analysis comparisons in order to choose with different criteria.

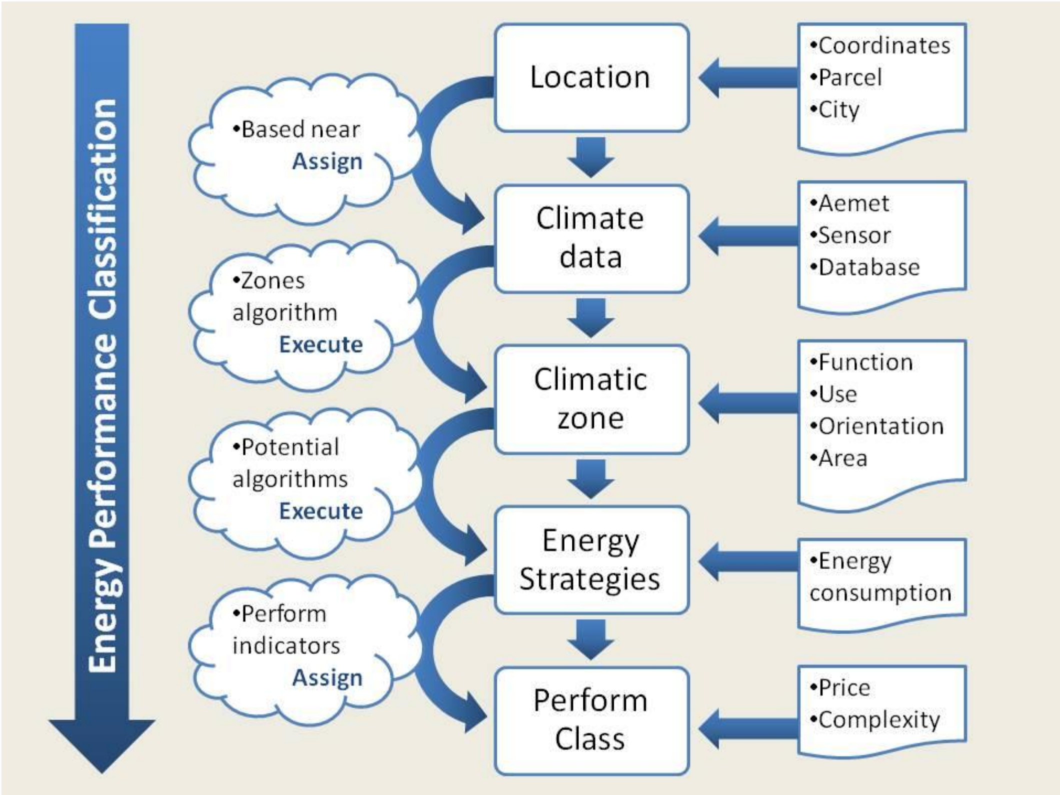

Figure 7.- Process for renewable energy sources

In some cases we stop here the process, but, when energy consumption for refrigerating, heating and hot water consumption is available, we continue and give more information to users, in order to aware them about their energy performance, which gives them a reference between them and the rest of users. In this work we consider this last step only for existing buildings where meters are available, because they provide a real reading and are much simpler than calculating hypothetical consumption considering all appliances installed or to be installed in the building.

Depending on the climatic zone where the building belongs, we get the reference energy performance indicators and apply classification algorithms described in (IDAE, 2009-1). With this result we can enrich our previous analysis adding a new variable to decide on which strategy we apply: price, complexity, energy savings and energy performance.

3.3.2. Implementation technology

Now we have data and have defined what processes to perform, we implement them in order to actually operate data to get a set of results. With them we will perform a comparison analysis on order to show users in a very easy way the advantages of one or other strategy to use. This would be able by graphically showing the balance between price, complexity and performance of different systems.

R (http://www.r-project.org/about.html) is an integrated suite of software facilities for data manipulation, calculation and graphical display. It includes an effective data handling and storage facility, a suite of operators for calculations on arrays, in particular matrices, a large, coherent, integrated collection of intermediate tools for data analysis, graphical facilities for data analysis and display either on-screen or on hardcopy, and a well-developed, simple and effective programming language which includes conditionals, loops, user-defined recursive functions and input and output facilities.

The term "environment" is intended to characterize it as a fully planned and coherent system, rather than an incremental accretion of very specific and inflexible tools, as is frequently the case with other data analysis software.

R can be easily extended via packages through the CRAN family of Internet sites covering a very wide range of modern statistics. One of them is the rrdf extension (Willighagen, 2011) which acts as a support for the Resource Description Framework allowing R to work with RDF data. Package rrdf provides methods to read and write RDF, and query RDF using SPARQL; add properties, triples or prefixes for namespaces; combine and query models, and so on. This makes it an appropriated tool to implement operations and formulae needed to operate data from models and integrate results back.

Moreover, profiting other R core functionalities we could perform “what if” scenarios comparing the outputs from the application of the different strategies provided: some constructive systems could accomplish the limit thermal transmittance, but may be a relevant difference in the context of complexity or price (Figure 10).

For the first process we should find which sensor having available the weather data needed are closest to our location. A buffer expressed as a range of validity (4 hundredths of a degree -2 up and 2 down- from the location of the building) for the values of the coordinates of the weather stations is performed. This operation is repeated until the first weather station is found. Then the extraction of the data will be performed. The only input data by the user is then the location. The output is a collection of climate data. As an example, part of the R code for this process can be consulted on Annex C.

To classify our location into a climate zone, the climate zones algorithms defined in CTE DB-HE are performed. The input data is the previous collection of climate data, and the output is the name of a zone which will rule the climate parameters of the location.

Being the CTE-DB-HE tables of parameters also modeled and stored as Linked Open Data, the parameters process is performed. The input data is the previous climatic zone and the limits and openings of the building with their orientations, this is, the building model. The output is a collection of functionalities and orientations with their limit solar factor and thermal transmittance.

To get the best available constructive systems, we crawl the catalogue of constructive systems and extract those which accomplish the climate parameters. The input data is the previous collection. The output data is a list of constructive systems attached to each item of the input data.

From climate zones and climate parameters we can also apply the potential power algorithms for RES systems described in (Dixon et al. 1999), (Suri et al. 2007), (Voivontas et al. 1998) or (http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy). The input will be the climate parameters and the building spaces and uses (susceptible of receiving some RES installation). The output is the RES systems available and their power supply.

The performance process needs these systems as input data and the actual energy consumption of the building. Applying algorithms described in (IDAE, 2009-1), the output is the energy Class, from A to G.

Finally, comparing all systems provided, the user can choose the desired system depending on their characteristics: price, complexity, performance, and so on.

3.3.3. User interface

Some tools for visualizing LOD are explained in section 2, but here our interest is to explain how we think all this work should be public accessible for regular users to get a useful understandable result.

In this context, a GIS tool to make location input data an easy task will be convenient. Also for visualizing the results as thematic maps with the different final outputs (potential solar power, solar heating, wind power, water storage, energy performance accomplishment when using certain constructive system…) represented in points or parcels around the studied location.

A desktop tool, based on GVSIG, QuantumGIS or other open source software would perform fast and provides the advantage of adding new data owned by the user easily. In the other hand, it needs installation and updating and involves more functionality, which in this case, trying to arrive to regular users, may be more an inconvenient than an advantage. Finally, it is based only in the user machine.

Figure 8.- Possible application mockup using GoogleMaps

A Web Service is then a suitable tool since is the most broadly accessible way for users to get a result from anywhere they are. It will offer a tailored interface providing only the functionality for which it has been designed. Being online is almost a need for the objectives of Linked Data initiatives, since we want both share our results and re-use others ones. As a matter of coherence, our service may be online, which can be the major inconvenience since not all people has access to the internet, although this is the trend.

Moreover we need online computing and access to data, both our own data and base maps served by SDIs or initiatives like OSM, so internet connectivity is always a limitation.

GoogleMaps, Open Layers, ESRI server or even map4rdf could be a solution for implementing visualization. As suggested in Figure 8, the objective is to point a location in a map and get all results from the running of the model (or a thematic map as explained before). Of course some additional data will be asked by means of popping dialogue boxes. In next section, the use case, we will see which these data are.

4. USE CASE

To better explain the model described in the previous section, we show below a use case based on an existing house, located in a residential building in Valencia (Spain), whose accomplishment of applicable normative and energy performance is unknown. We will apply our model and find out which measures, both active and passive, are applicable and which of them provide us a better energy performance.

4.1. Data

First of all we are showing the datasets created by applying the data models described in section 3. Only the ones related to this specific use case are modeled: the building, the parameters related to its location and the systems in use and/or susceptible to be in use (http://www.anasanhue.hostzi.com/joomla/images/lodbless_gandia_74.rdf), as seen in Figure 9, done with RDFGravity (Goyal and Westenthaler,).

4.1.1. Building

As seen in 3.1, the building data model is divided into three blocks of knowledge: its location, its energy consumption and its distribution.

Being located in Valencia, in a known parcel named 5223603YJ2752C0006UD, with known coordinates (725.240, 4.372.320, UTM coordinates in meters; 39.470º, -0.377º geographical coordinates), we will provide the three possibilities, city, parcel and point, although only the most accurate (point) will be used for running the model and relate our building with the location data.

For the energy consumption we use the energy supplier metering for electric power, water use and natural gas. No RES power is in use, but we take into account the potential power from a photovoltaic installation, in order to later on, perform some assessment.

For building distribution, we have a two bedroom house, with living room, bathroom, toilet, kitchen, terrace and storing room, with known areas and relations between them. Each space has known limits, being interior partitions, façades, floors and roofs, and whose orientation, constructive system and area are also known.

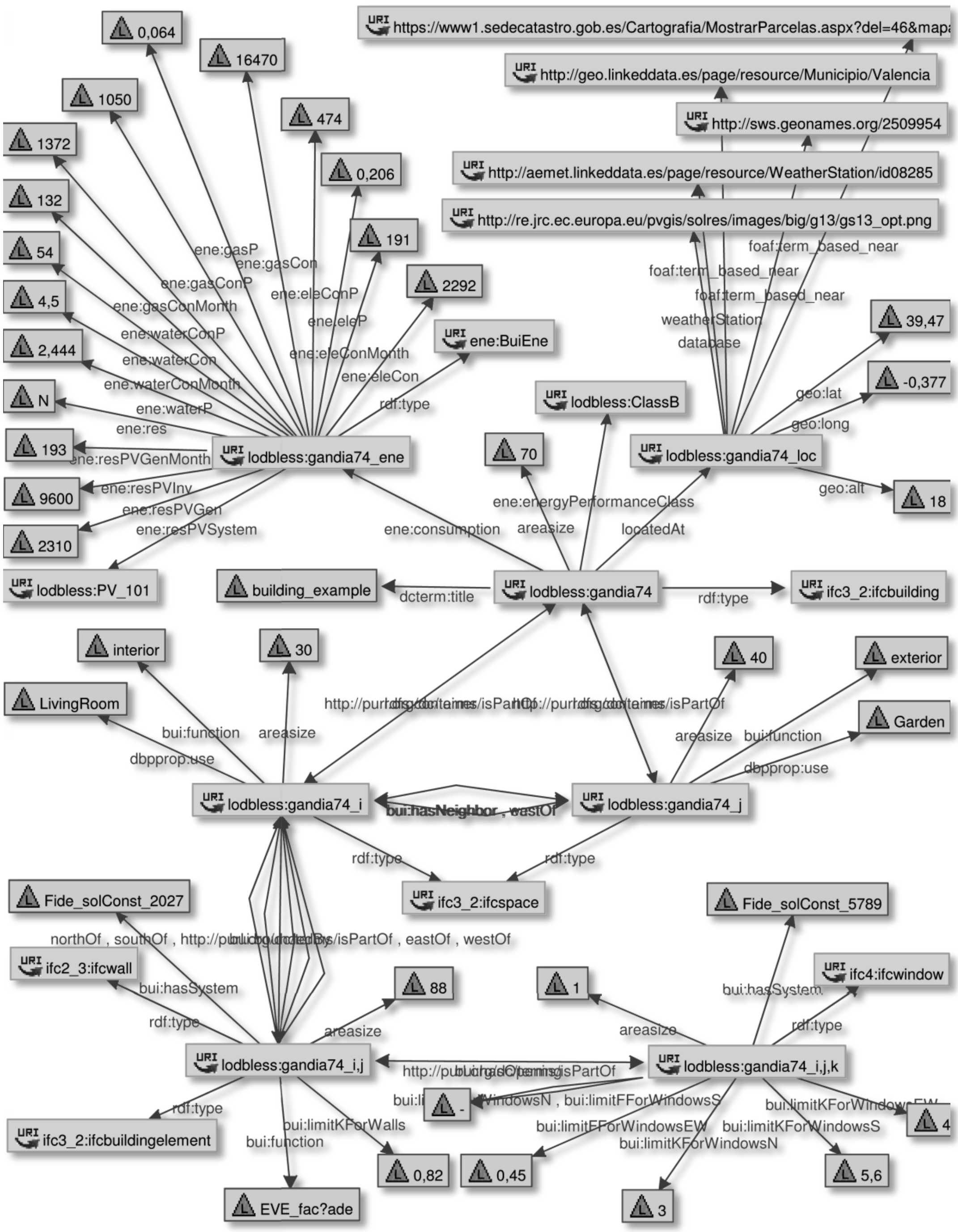

Figure 9.- Use case RDF graph

By applying the building data model and using the vocabularies described in section 3.3, we get the dataset where all information is stored. We can see an excerpt in the Table 3 with enough data about the building to run the processes described in section 3.2.

subject	predicate	object
Gandia74	rdf:type	ifcBuilding
Gandia74	tisc:locatedAt	Gandia74_loc
Gandia74	dbpp:buildingType	dbpedia:House
Gandia74	tisc:areasize	70
Gandia74	ene:consumption	Gandia74_ene
Gandia74	rdfs:container	0… Gandia74_n
…	…	…
Gandia74_loc	foaf:based_near	http://sws.geonames.org/2509954
Gandia74_loc	foaf:based_near	http://geo.linkeddata.es/page/resource /Municipio/Valencia
Gandia74_loc	foaf:based_near	https://www1.sedecatastro.gob.es/ Cartografia/MostrarParcelas.aspx?del=46&mapa=5,242&coorx=725243.2218675179&coory=4372330.4878048785&huso=30
Gandia74_loc	geo:lat	39,47
Gandia74_loc	geo:long	-0,377
Gandia74_loc	geo:alt	18
Gandia74_loc	loc:weatherStation	Estacion 08285
Gandia74_loc	loc:database	Classic_PVGIS
…	…	…
Gandia_74_ene	ene:eleCon	2292
Gandia_74_ene	ene:eleP	0,206
Gandia_74_ene	ene:eleConP	474
Gandia_74_ene	ene:eleConMonth	191
Gandia_74_ene	ene:gasCon	16470
Gandia_74_ene	ene:gasP	0,064
Gandia_74_ene	ene:gasConP	1050
Gandia_74_ene	ene:gasConMonth	1372
Gandia_74_ene	ene:waterCon	54
Gandia_74_ene	ene:waterP	2,444
Gandia_74_ene	ene:waterConP	132
Gandia_74_ene	ene:waterConMonth	4,5
Gandia_74_ene	ene:res	N
Gandia_74_ene	ene:resPVSystem	PV_101
Gandia_74_ene	ene:resPVInv	
Gandia_74_ene	ene:resPVGen	2310
Gandia_74_ene	ene:resPVGenMonth	193
Gandia_74_ene	ene:energyPerformanceClass	B
…	…	…
Gandia74_i	dcterms:isPartOf	Gandia74
Gandia74_i	rdf:type	ifcSpace
Gandia74_i	rdf:type	cityRoom
Gandia74_i	tisc:areasize	30
Gandia74_i	dbpprop:use	“livingRoom”
Gandia74_i	bui:hasNeighbor	0… Gandia74_n
…	…	…
Gandia74_i,j	dcterms:isPartOf	Gandia74_i
Gandia74_i,j	rdf:type	ifcBuildingElement
Gandia74_i,j	rdf:type	cityBoundarySurface
Gandia74_i,j	rdf:type	ifcWall
Gandia74_i,j	rdf:type	cityWallSurface
Gandia74_i,j	bui:hasOpening	0… Gandia74_i,j,k
Gandia74_i,j	tisc:areasize	10
Gandia74_i,j	bui:function	EVE_fachada

Gandia74_i,j	bui:hasSystem	Fide_solConst_2027
Gandia74_i,j	dbpprop:orientation	SE
Gandia74_i,j	bui:limitKForWalls	0,82
…	…	…
Gandia74_i,j,k	dcterms:isPartOf	Gandia74_i,j
Gandia74_i,j,k	rdf:type	ifcBuildingOpening
Gandia74_i,j,k	rdf:type	cityOpening
Gandia74_i,j,k	rdf:type	ifcWindow
Gandia74_i,j,k	rdf:type	cityWindow
Gandia74_i,j,k	tisc:areasize	4
Gandia74_i,j,k	bui:hasSystem	Fide_solConst_5789
Gandia74_i,j,k	bui:limitKForWindowSESW	5,6
Gandia74_i,j,k	bui:limitFForWindowSESW	0,5
…	…	…

Table 3.- Excerpt from Gandia74 data

Location data is entered manually, i.e. by clicking on a map. Other data in blue are also entered manually, at least the first time using this building, since is the user who knows how the building is. The rest of data are inferred by the knowledge defined in the ontology that rules this model, described in 3.3. With time, we will build a building database on which perform more complex studies.

4.1.2. Location

As seen in previous section, the location model is focused in this work into the climate data that affects building envelope constitution and profitable renewable energy resources. Being our building located in Valencia (http://geo.linkeddata.es/page/resource/Municipio/Valencia), in parcel 5223603YJ2752C0006UD, and known coordinates (725.240, 4.372.320, UTM coordinates in meters; 39.470º, -0.377º geographical coordinates), we will provide the three possibilities, city, parcel and point, although only the most accurate (point) will be used for running the model and relate our climate data with the building data.

By applying an iterated fixed distance buffer of 1.000 m (based on the observed distribution of Aemet sensors and other sensor sources as Meteoclimatic initiative - not still available as Linked Open Data), we choose an identified sensor from where to extract weather data needed. In case we don’t have access to all weather data we need in the selected sensors from Aemet and Meteoclimatic, we can try a city related database, like the one from INE (National Institute for Statistics) (http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t43/a012/a1998&file=pcaxis), to feed our dataset.

subject	predicate	object
Gandia74_loc	foaf:based_near	http://sws.geonames.org/2509954
Gandia74_loc	foaf:based_near	http://geo.linkeddata.es/page/resource/Municipio/Valencia
Gandia74_loc	foaf:based_near	https://www1.sedecatastro.gob.es/..coorx=725243.2218675179&coory=4372330.4878048785&huso=30
Gandia74_loc	geo:lat	39,47
Gandia74_loc	geo:long	-0,377
Gandia74_loc	geo:alt	18
…	…	…
Gandia74_loc	loc:weatherSensor	http://aemet.linkeddata.es/page/resource/WeatherStation/id08285
Gandia74_loc	loc:weatherSensor	http://www.meteoclimatic.com/perfil/ESPVA4600000046021A
Gandia74_loc	loc:database	INE_database
Gandia74_loc	loc:database	Classic_PVGIS
…	…	…
Gandia74_loc	loc:gdJanuary	263
Gandia74_loc	loc:gdFebruary	218
Gandia74_loc	loc:gdJune	85
Gandia74_loc	loc:gdJuly	164
Gandia74_loc	loc:gdAugust	193
Gandia74_loc	loc:gdSeptembre	135
Gandia74_loc	loc:gdDecembre	220
Gandia74_loc	loc:radJanuary	104
Gandia74_loc	loc:radFebruary	112
Gandia74_loc	loc:radJune	178
Gandia74_loc	loc:radJuly	187
Gandia74_loc	loc:radAugust	183
Gandia74_loc	loc:radSeptembre	164
Gandia74_loc	loc:radDecembre	92,4
Gandia74_loc	loc:irradiation	1750
…	…	…
Gandia74_loc	loc:climaticZone	A4
Gandia74_loc	bui:limitKForWalls	0,82
Gandia74_loc	bui:limitKForFloors	0,52
Gandia74_loc	bui:limitKForRoofs	0,45
Gandia74_loc	bui:limitKForWindowsN	3,3
Gandia74_loc	bui:limitKForWindowsEW	4,9
Gandia74_loc	bui:limitKForWindowsS	5,7
Gandia74_loc	bui:limitKForWindowsSESW	5,7
Gandia74_loc	bui:limitFForRoofWindows	0,3
Gandia74_loc	bui:limitFForWindowsN	-
Gandia74_loc	bui:limitFForWindowsEW	-
Gandia74_loc	bui:limitFForWindowsS	-
Gandia74_loc	bui:limitFForWindowsSESO	-
…	…	…

Table 4.- Excerpt from Gandia74_loc data

By applying stored CTE formulas on this data, we get the climatic zone that provides us with thermal and energy relevant parameters. We will see this process in the next sections.

The eventuality of not having enough data from sensors and linkable databases repeating is the cause why our model has the next property defined: the climatic zone. If no climatic source of data is available, we always can use the tabulated climatic zone form CTE-DB-HE, which only needs a city name and altitude (available on http://sws.geonames.org/2509954) to perform a result, instead of trying to accurately calculate it from real actual data.

With climate zone (B3 in this case) known, location and weather data extracted from climate sensors and databases (not Linked Open Data in this use case), we have the parameters needed to run our process: thermal transmittance classified into function and orientation (to link with building model) from CTE-DB-HE tables; mean accumulated rainwater in a year per square meter (available to store water - to link with building model) from INE in this case; annual solar PV potential by month and square meter (available to install PV panels- to link with building model) from PVGIS (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#); and mean wind speed and direction (to link with building model depending on available space for rotor and hub and orientation) from INE in this case, in order to provide energy efficiency strategies.

By applying the location data model and using the vocabularies described in 3.3, we get the dataset where all information is stored. We can see an excerpt in the Table 4 with enough data to run the processes described in section 3.2.

Data in blue are entered manually, i.e. by clicking on a map. The rest of data are inferred by the knowledge defined in the ontology that rules this model, described in 3.3.

4.1.3. Systems

Finally for the systems in use for this use case we distinguish between constructive systems for passive measures feeding and resulting from the energy demand limitation process and the active systems, being in this work the renewable energy resources taken into account in the energy performance and RES process. As described in section 3, systems are defined in three blocks of knowledge: their location, their elements and their properties.

In this use case we find four types of systems in use: the constructive system for interior partitions and party walls (and their openings - doors), the constructive system for façades (and their openings - windows), the constructive system for floors, and the one for roofs.

No renewable energy system is in use, but knowing the potential resources of our location, we could calculate the potential savings if we use one RES system, like a photovoltaic installation, chosen here to match electric consumption needs defined in the building dataset. All systems have their location defined by the limit or space they occupy, thus they are related with the building model.

subject	predicate	object
Fide_solConst_2027	rdf:type	Constructive_System
	rdf:type	EVE_faÇade
	tisc:locatedAt	Gandia74_i,j
	sys:complexity	3
	rdfs:container	MAT_73… MAT_239
	price	-
	transmittance	0,63
…	…	…
MAT_73	rdf:type	Material
	dcterms:isPartOf	Fide_solConst_2027
	price	-
	vapourResistance	10
	width	1,5
	density	2100
	thermalResistance	0,008
	specificHeat	1000
	thermalConductivity	1,8
…	…	…
MAT_86	rdf:type	Material
	dcterms:isPartOf	Fide_solConst_2027
	price	
	vapourResistance	10
	width	14
	density	1170
	thermalResistance	0,32
	specificHeat	1000
	thermalConductivity	0,438
…	…	…
MAT_239	rdf:type	Isolation_mat
	dcterms:isPartOf	Fide_solConst_2027
	price	
	width	3
	thermalResistance	0,909
	thermalConductivity	0,033
…	…	…

Table 5.- Excerpt from Fide_solConst_2027 data

Each system is formed by a number of elements, being them the second block of knowledge. The catalogue of constructive systems (http://www.elementosconstructivos.codigotecnico.org/Pages/BusquedaSC.aspx) gives us in this use case the properties we need for each material being an element of the constructive system: a brick layer, an isolation material, an air chamber, plaster and/or coating layer, concrete layers, tiles, window frames, glazing and shutters… The xmlFIDE format provides us with the needed properties: the order, the thermal transmittance, the solar factor, the thickness, and sometimes the price, very interesting to perform some "what if" scenarios.

From same xmlFIDE file we get the global properties of the system, being them the complexity or number of elements, global thermal K and price per square meter. The whole catalogue is available in xmlFIDE format, and storing it as a Linked Open Data database would make it really useful for this kind of purposes.

The data needed to run the PVGIS model in order to calculate the convenience of one or another PV system is defined also, but in this case, no elements are defined but only location and properties: its location in a house space gives us the area of the installation, its tracking options gives us the complexity and its type and efficiency rule its potential power supply.

By applying the systems data model and using the vocabularies described in 3.3, we get the dataset where all information is stored. We can see an excerpt in Table 5 and Table 6 with enough data to run the processes described in section 3.2.

subject	predicate	object
PV_101	rdf:type	RESSystem
	rdf:type	RES_PV_system
	tisc:locatedAt	Gandia74_j
	sys:complexity	1
	rdfs:container	CdTe
	tisc:areasize	16
	sys:efficiency	10
	price	-
…	…	…

Table 6.- Excerpt from PV_101 data

The only data in blue here is the location, entered manually by choosing the space or limit where they are installed, since we know it because we are talking about an existing building. In the case of a new building, the model will give us a list of possibilities classified by function and orientation of a limit, and area of spaces defined as susceptible of receiving a RES. The rest of data are inferred by the knowledge defined in the ontology that rules this model, described in 3.3.

4.2. Processes

We simulate in this section the application of the model, pointing which input data are needed in each step described in 3.2, the operations done with them and the output data, published or used as input for the next step using the data from the described use case.

Then we assess the results by comparing characteristics from the different solutions provided, that will help user to make an informed decision on what to do with how much money, time or resources to spend and how much energy and therefore money savings will he get.

4.2.1. Application

For the based near process (Table 7) we should find which weather sensor is the closest to our location. A buffer expressed as a range of validity (4 hundredths of a degree -2 up and 2 down- from the location of the building, equivalent to around 4.000m bounding box size) for the values of the coordinates of the weather stations is performed. This operation is repeated until the first weather station is found. Then the extraction of the data will be performed. The only input data by the user is then the location. The output is a collection of climate data.

First we need to know the building coordinates. The SPARQL query would be:

```
SELECT ?lat, ?long, ?alt
WHERE {
<http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat.
<http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#long> ?long.
<http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#alt> ?alt. }
```

The SPARQL query for the buffer process would be as seen below:

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>
SELECT ?weatherStation, ?lat, ?long, ?alt
WHERE {
?weatherStation geo:location ?location .
?location geo:lat ?lat .
?location geo:long ?long .
?location geo:alt ?alt .
FILTER ( xsd:double(?lat) < xsd:double("39.49") ) .
FILTER ( xsd:double(?lat) > xsd:double("39.45") ) .
FILTER ( xsd:double(?long) < xsd:double("-0.357") ) .
FILTER ( xsd:double(?long) > xsd:double("-0.397") ) . }
```

The SPARQL query for the extraction process (from AEMET data) would be:

```
PREFIX aemetonto: <http://aemet.linkeddata.es/ontology/>
PREFIX aemetWeatherStation: <http://aemet.linkeddata.es/resource/WeatherStation/>
PREFIX aemetTemperatureAmbientProperty:
<http://aemet.linkeddata.es/resource/TemperatureAmbientProperty/>
PREFIX ssn: <http://purl.oclc.org/NET/ssnx/ssn#>
PREFIX time: <http://www.w3.org/2006/time#>
SELECT ?year, ?month, ?day, ?hour, ?valueOfObservedData
WHERE {
?observation aemetonto:valueOfObservedData ?valueOfObservedData.
?observation ssn:observedBy aemetWeatherStation:id08285 .
?observation ssn:observedProperty aemetTemperatureAmbientProperty:TA .
?observation aemetonto:observedInInterval ?observedInterval .
?observedInterval time:hasBeginning ?instant .
?instant time:inDateTime ?dateTimeDescription .
?dateTimeDescription time:year ?year .
?dateTimeDescription time:month ?month .
?dateTimeDescription time:day ?day .
?dateTimeDescription time:hour ?hour . }
ORDER BY ?year ?month ?day ?hour
```

The results of both queries can be consulted on Annex B and part of the R code is on Annex C. These results must be operated to get the values shown in Table 7.

input	process	output	
location:	buffer:	sensors:	
39,47ª	at 4.000m, 8.000m, 12.000m…	aemet /WeatherStation/id08285	
-0,377ª		meteoclimatic /ESPVA4600000046021A	
18m		PVGIS at 39,47ª, -0,377ª, 18m	
	extraction & filtering:	climate data:	
	Degrees day at base 20 is calculated from the temperature values in 1 hour minus 20. The resulting positive values are added and divided by 24. For a month, add up all the values.	loc:gdJanuary	263
		loc:gdFebruary	218
		loc:gdJune	85
		loc:gdJuly	164
		loc:gdAugust	193
		loc:gdSeptembre	135
		loc:gdDecembre	220
	Radiation is extracted form PVGIS database at our location	loc:radJanuary	104
		loc:radFebruary	112
		loc:radJune	178
		loc:radJuly	187
		loc:radAugust	183
		loc:radSeptembre	164
		loc:radDecembre	92,4
		loc:irradiation	1750
	…	…	…

Table 7.- Based near process inputs and outputs

To classify our location into a climate zone, the climate zones algorithms defined in CTE-DB-HE are performed (Table 8). The input data is the previous collection of climate data, and the output is the name of a zone which will rule the climate parameters of the location.

input		process	output	
climate data:		climate zone data:	climate zona data:	
loc:gdDecembre	220	The average degree-days base 20 winter for the months January, February, and December.	gdWinter	234
loc:gdJanuary	263			
loc:gdFebruary	218			
loc:gdJune	85	The average degree-days base 20 winter for the months June, July, August,and September.	gdSummer	144
loc:gdJuly	164			
loc:gdAugust	193			
loc:gdSeptembre	135			
loc:radDecembre	92,4	The average cumulative global radiation for the months of January, February, and December.	radWinter	103
loc:radJanuary	104			
loc:radFebruary	112			
loc:radJune	178	The average cumulative global radiation for the months of June, July, August and September	radSummer	178
loc:radJuly	187			
loc:radAugust	183			
loc:radSeptembre	164			
		climate zone algorithm:	climate zone:	
		From CTE-DBE-HE Document for Energy Conservation. Appendix D Climate Zones		A4
		From CTE-DBE-HE Document for Energy Conservation. Appendix D. Table D.1		B3
…		…	…	

Table 8.- Climatic Zones process inputs and outputs

Being the CTE-DB-HE tables of parameters also modeled and stored as Linked Open Data, the parameters process is performed (Table 9). We can also apply the potential power algorithms for RES systems described in (Dixon et al. 1999), (Suri et al. 2007), (Voivontas et al. 1998) or (http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy). The input data is the previous climatic zone and some previous climatic properties and the limits and openings of the building with their orientations, this is, the building model. The output is a collection of functionalities and orientations with their limit solar factor and thermal transmittance and the potential power supply from RES.

To get the best available constructive and RES systems, we crawl the catalogue of constructive systems and our database stored as LOD with RES systems, and extract those which accomplish the climate parameters and fulfill energy consumption (Table 10). The input data is the previous collection and the energy consumption. The output data is a list of constructive and RES systems attached to each item of the input data.

input		process	output	
climate zone:		energy demand limitation:	Thermal K:	Solar F:
	A4	From Tables 2.2 CTE-DB-HE		
building data:				
gandia_74_i	living			
gandia_74_i,j	wallN		0,94	-
gandia_74_i,j	wallS		0,94	-
gandia_74_i,j	wallE		0,94	-
gandia_74_i,j	wallW		0,94	-
gandia_74_i,j,k	winN		3,80	-
gandia_74_i,j,k	winS		5,70	0,59
gandia_74_i,j,k	winE		5,20	0,43
gandia_74_i,j,k	doorW		5,20	0,43
gandia_74_i,k	floor		0,53	-
gandia_74_i,l	roof		0,50	-
gandia_74_i,l,m	roofWin		-	0,29
		PV potential algorithms:	PV power:	
Gandia_74_i,j	garden	From PVGIS (Suri et al. 2007)	1900 -2500	
climate data:				
loc:irradiation	1750			
…		…	…	

Table 9.- Parameters process inputs and outputs

input			process	output
function	K:	F:	crawl catalogue:	constructive system:
wallN	0,94		LOD constructive systems dataset extracted from constructive systems catalogue in xmlFIDE format	Fide_solConst_2027
wallS	0,94	-		Fide_solConst_2027
wallE	0,94	-		Fide_solConst_2027
wallW	0,94	-		Fide_solConst_2027
winN	3,80	-		Fide_solConst_5789
winS	5,70	0,59		Fide_solConst_5789
winE	5,20	0,43		Fide_solConst_5789
doorW	5,20	0,43		Fide_solConst_5789
floor	0,53	-		-
roof	0,50	-		-
roofWin	-	0,29		-
energy consumption:			crawl RESSystems dataset:	RES system
Electricity	2292		LOD constructive system dataset from PVGIS web Service results	PV_101
…			…	…

Table 10.- Systems process inputs and outputs

input		process	output
energy consumption:		energy performance:	energy Class:
Water:	-	Algorithms described in Anex 1 from (IDAE, 2009-1)	A
Gas:	-		
Electricity	2292		
RESSystem:			
	PV_101		
	…		

Table 11.- Energy Class process inputs and outputs

The performance process (Table 11) needs these RES systems as input data and the actual energy consumption of the building. Applying algorithms described in (IDAE, 2009-1), the output is the energy Class, A to G (from best to worst perform).

This is step by step model evolving from first input data. In each step we don't show all data need for running the process but only new data, like in this case, where location is very important but we don't show it again since it was the first data we input.

Finally, we would like to note that this is just a limited use case where not all possibilities of the model are explored.

4.2.2. Assessment

In a complete process, we will usually provide more than one constructive and RES system, which will provoke, depending on which we choose, a different energy Class, but also different cost and complexity. Comparing all systems provided, the user can choose the desired system depending on their characteristics.

In order to help user to take an informed decision, an assessment of results and hypothesis is performed in an understandable way to show the differences and consequences of choosing each different solution. This way is a graphical way, as the fake shown in Figure 10.

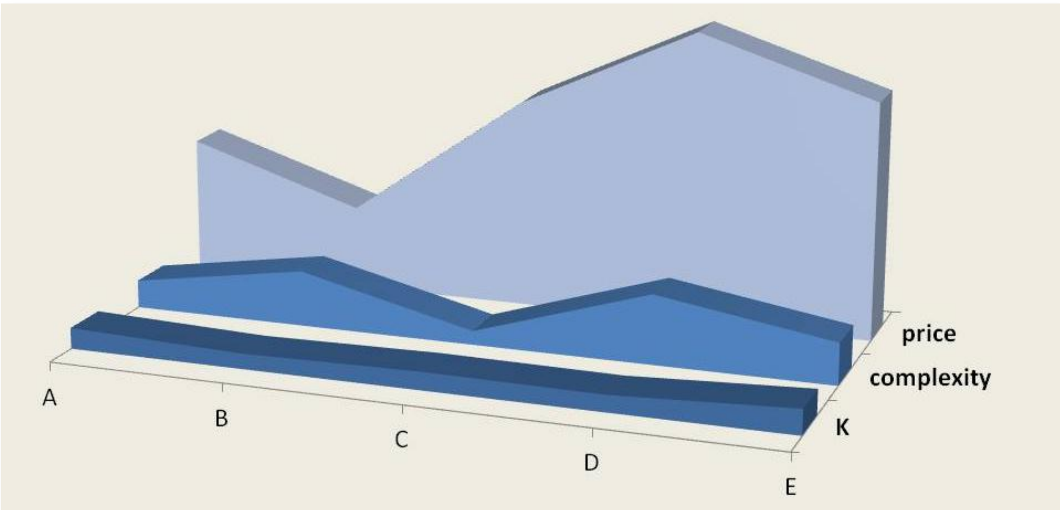

Figure 10.- Comparison between constructive systems

Applying the model on our use case, we have got a constructive system called Fide_solConst_2027, which has 3 elements to get a thermal transmittance of 0,82 W/m2K, with an unknown price, which we are suggesting to be 40 €/m2. We call this system A.

But in the catalogue of constructive systems are more than this system that fits the only constraint of the model, which is the thermal transmittance. This is, that any other system whose K is under 0,95 W/m2K must be shown in the list of outputs and can be chosen.

Let's say that we have four other systems whose K is under 0,95 W/m2K: B, C, D and E. They should have a variety of values for both K, number of elements and price. The assessment will simply consist of showing the properties of each system in a graph, so the user can decide if he wants to spend more money, or a simpler system to build or the most isolating one.

In the other hand, this use case was supposing our building has no RES system installed, but when applying the model, a certain PV system has shown that it could supply almost all the electricity consumed by the building along the year. This means energy savings, CO_2 releases savings, and some time from now, money saving. We could perform a similar graph where these variables are shown, as seen in fake Figure 11

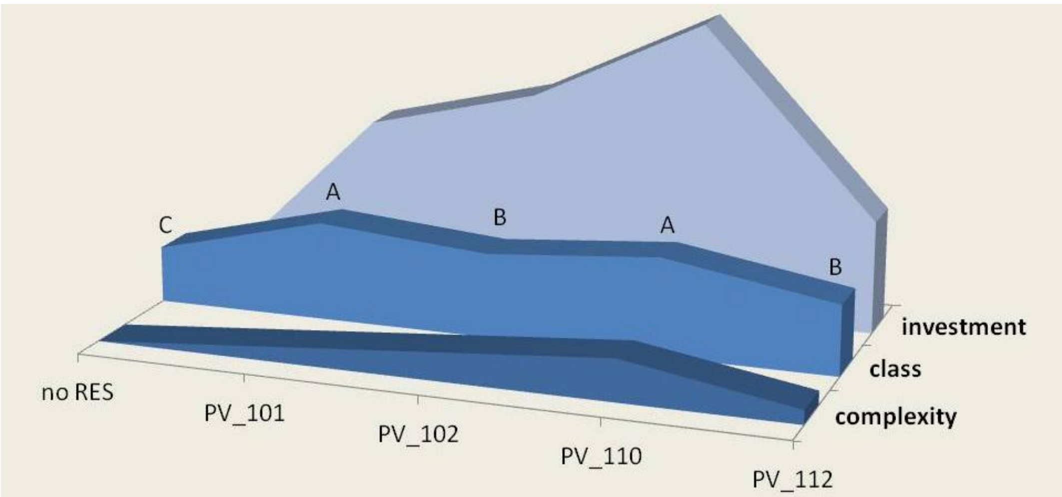

Figure 11.- Comparison between RES systems

5. CONCLUSIONS

From the work described in this document we can discuss the achievements and extract some lessons learned as conclusion. Many things are explained and described and fewer things are done. The latter provides a good chance for continue working on this passionate field, and is exposed in the future work.

5.1. Achievements

The objective of finding out which data are necessary and sufficient to get a result was achieved and resulted in a set of data understandable for non expert users, like finding the location of their building, defining energy consumption as available from meters or describing which room is located north/east/south… from another room. But in the case of constructive materials or RES systems in existing buildings, the definition of materials is found not so accessible for non expert users.

The reduction of data needed to be provided by users has been achieved by finding, accessing and re-using data are available by other means and linking them into our model. We have found many related data for weather observations or constructive materials. Most of them were trying to maintain a sense of coherence, including semantics and structure, but only a few of them were real Linked Open Data.

The latter, like AEMET data, were very useful, since we could perform queries on them to provide real time data into our model, avoiding preset values statistically interpolated from very few observations. As an example, in our use case, climate zone from CTE tables was B3 for the building location, but when calculating it from real measurements we got an A4 zone, which changes limits for thermal transmittance and solar factor for materials to be used.

Other data would be really useful if complete their path onto the Linked Open Data philosophy, like the materials catalogue provided by Spanish Government, following international standards on data structure and semantics, but not accessible for querying and getting results from it.

A model has been proposed to connect data and allow them to perform together. The operations that these data have to complete to get a useful result are described and explained through a use case where is shown how data needed are available and understandable for non expert users and results show savings for user and environment in an easy direct way. By reading this work one could repeat the described steps to test some building.

5.2. Lessons learned

From the beginning of this master in science in geospatial technologies, I knew my topic will be related to energy efficiency, since it is strongly related to location conditionings and I had a background on it, but my fear about the complexity of the field was stopping me, I tried other topics, but finally I surrender and addressed the issue.

My first lesson learned is that I was not mistaken. Many data are taken into account for energy efficiency solutions, moreover when it is a primary concern for society these days. Lots of efforts are done and many initiatives are underway collecting and manipulating useful data for energy efficiency systems, energy performance, environmental conditions…, unfortunately, not in a very coordinated way.

Many data is available in very different formats, scales and sources, making almost mandatory the conversion and transforming of these data. Moreover, the complexity and variety of the processes makes them need very concrete and specific kinds of data to run. This provokes that not all data available are useful for all topics, contexts, or processes.

This is, we have access to many data which almost fit our necessities, but in many cases, the need of transforming them and add new ones makes Scientifics consider that is easier to build up a new set of data, completely coherent and covering all need of their process. This provokes duplicity of resources, differing in small details, and confusing new users on which data should they use.

The use of ontologies and semantic content, and the availability of this structured meaningful content on the internet have tried to solve this issue. The linkage of resources with their semantics facilitates the re-use of data and enables users to query and extract the needed data and collaborate adding in the structure new terms.

Linked Open Data initiative has a huge amount of data linked, but still the tools and discovery services are emerging, and it is not easy to query and find what you are looking for.

Finally, the too complex models existing for energy efficiency analysis and the amount of specific data needed to run them, makes them unavailable for non-expert people concern with environment and wanting to collaborate by the means they have, this is, how can they save energy and CO2 releases by better building their houses?

This work has tried to re-use the most quantity of existing terms fitting an energy efficiency analysis model simplified to the maximum. The process has been explained step by step. The data needed has been described carefully, and the expected results have been previewed in a general scope.

Simplicity should involve people in using and feeding models to, with time, build a database with coordinated building data on which perform more complex or expert-based studies. Simple results from simple models with simple data may be enough for non-expert people to get involved with energy efficiency strategies, loss their fear to big investments and see their revenues in money and especially in environment.

5.3. Future work

As said before, this work has described a lot and done a few. In the use case exposed, we input many data and make calculations by hand. Therefore, the natural continuing of this work is to implement the tools, services and portals to perform the manual searches and links done in this work automatically, by following the principles hereby exposed.

Structure and store all data available into Linked Open Data will be the first step. All tables and relations described in CTE should be linked in a semantic way with building database. The systems available as FIDE format should be also translated and semantically linked with it.

Then implement processes as Web Processing Services accessing data and performing each calculation. Modularity and standards use will improve availability, visibility and reusability of the model in other fields.

Finally publishing a web portal to make available the performance of the whole process will be the last step. Here the input of data will be guided by some wizards and the visualization of results will be presented in familiar and understandable formats, like balloons over the selected map location with lists, tables and graphs.

In other hand, a more step forward is the continuing of this work concept by incorporating real time information not only from environmental conditions, like weather data but with building conditions, like real-time electricity or water consumption, indoor temperatures or indoor light levels to rule a domotic system concerned with energy performance at any time during the building lifetime, and not only at the moment of receiving the energy Class certification.

Other path to follow could be the application of data mining techniques into the datasets stored and build a model for predictive energy performance classification.

BIBLIOGRAPHIC REFERENCES

A/RES/43/53. 1998. PROTECTION OF GLOBAL CLIMATE FOR PRESENT AND FUTURE GENERATIONS OF MANKIND. United Nations General Assembly. 70th plenary meeting 6 December 1988. Available on-lin on February the 2nd: http://www.un.org/documents/ga/res/43/a43r053.htm

AIDICO. 2011. ARQUITECTURA GENERAL DEL MODELO FÍSICO FIDE. v.2.4. Available on-line on January the 4th, 2012: http://www.fide.org.es/ index.php/descargas/cat_view/23-paquetes-de-desarrollo/36-modelo-de-datos/78-fide-24

Archer, C.L. and Jacobson, M.Z. EVALUATION OF GLOBAL WIND POWER. Journal of Geophysical Research, Vol. 110, D12110. Available on-line on February the 2nd: http://www.stanford.edu/group/efmh/winds/2004jd005462.pdf

Autodesk. GREEN BUILDING STUDIO. GETTING STARTED WITH WEB SERVICE TOOLS FOR WHOLE BUILDING ANALYSIS. Available on-line on February the 2nd: http://images.autodesk.com/adsk/files/getting+started+with+green+ building+studio+web+service_final.pdf

Berners-Lee, T., Chen, Y., Chilton, L. Connolly, D., Dhanaraj, R., Hollenbach, J., Lerer, A. and Sheets, D. 2006. TABULATOR: EXPLORING AND ANALYZING LINKED DATA ON THE SEMANTIC WEB. In Proceedings of the 3rd International Semantic Web User Interaction Workshop. Available on-line on January the 11th, 2012 on: http://swui.webscience.org/swui06/papers/Berners-Lee/Berners-Lee.pdf

Bizer, C. and Cyganiak, R. 2006. D2R SERVER – PUBLISHING RELATIONAL DATABASES ON THE SEMANTIC WEB. Proceedings of the 5th International Semantic Web Conference (2006). Available on-line on January the 11th, 2012 on: http://richard.cyganiak.de/2008/papers/d2r-server-iswc2006.pdf

Bizer, C., Cyganiak, R. and Heath, T. 2007. HOW TO PUBLISH LINKED DATA ON THE WEB. Available on-line on January the 11th, 2012 on: http://www4.wiwiss.fu-berlin.de/bizer/pub/LinkedDataTutorial/20070727/

Bizer, C., Heath, T. and Berners-Lee, T. 2009. LINKED DATA - THE STORY SO FAR. T., Hepp, M., and Bizer, C. (eds.). Special Issue on Linked Data, International Journal on Semantic Web and Information Systems (2009) Volume: 5, Issue: 3, Publisher: Elsevier, Pages: 1-22. Available on-line on January the 11th, 2012 on: http://tomheath.com/papers/bizer-heath-berners-lee-ijswis-linked-data.pdf

Bonino, D. and and Corno, F. 2008. DOGONT - ONTOLOGY MODELLING FOR INTELLIGENT DOMOTIC ENVIRONMENTS. A. Sheth et al. (Eds.): ISWC 2008, LNCS 5318, pp. 790–803, 2008. Springer-Verlag Berlin Heidelberg 2008. Available on-line on January the 11th, 2012 on: http://www.springerlink.com/content/75278542307m17h0/ fulltext.pdf

Bry, F., Hattori, T., Hiramatsu, K., Okadome, T., Wieser, C. and Yamada, T. 2005. CONTEXT MODELLING IN OWL FOR SMART BUILDING SERVICES. In Proceedings of Grundlagen von Datenbanken. 2005, pp.38-42. Available on-line on January the 11th, 2012 on: http://citeseerx. ist.psu.edu/viewdoc/summary?doi=10.1.1.70.520

Cheng, G. and Qu, Y. 2009. SEARCHING LINKED OBJECTS WITH FALCONS: APPROACH, IMPLEMENTATION AND EVALUATION. 50 International Journal on Semantic Web and Information Systems, 5(3), 50-71, July-September 2009. Available on-line on January the 11th, 2012 on: http://ws.nju.edu.cn/resources/publications/SearchinglinkedobjectswithFalcons_35 140cd8fa944e5d8986a2be3b6a2774.pdf

Clinton, B. 1994. EXECUTIVE ORDER 12906: COORDINATING GEOGRAPHIC DATA ACQUISITION AND ACCESS: THE NATIONAL SPATIAL DATA INFRASTRUCTURE, signed on April 11, 1994. Available on-line on February the 2nd: http://www.archives.gov/federal-register/executive-orders/pdf/12906.pdf

COM 2002/91/EC. 2002. DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL OF 16 DECEMBER 2002 ON THE ENERGY PERFORMANCE OF BUILDINGS. Official Journal of the European Communities. 4.1.2003. L 1/65. Available on-line on January the 4th, 2012: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do? uri=OJ:L:2003:001:0065:0065:EN:PDF

Crawley, D.B., Hand, J.W., Kummert, M. and Griffith, B.T. 2008. CONTRASTING THE CAPABILITIES OF BUILDING ENERGY PERFORMANCE SIMULATION PROGRAMS. Building and Environment, 43 (4). pp. 661-673. ISSN 0360-1323. Available on-line on January the 4th, 2012: http://strathprints. strath.ac.uk/6555/1/strathprints006555.pdf

Crawley, D.B. and Huang, Y.J. 1997. DOES IT MATTER WHICH WEATHER DATA YOU USE IN ENERGY SIMULATIONS? Building Energy Simulation User News, Spring 1997 – Vol 18, No. 1. Presented at the ACEEE 1996 Summer Study on Energy Efficiency in Buildings, 25-31 August 1996, Asilomar Conference Center, Pacific Grove, California. Available on-line on February the 2nd: http://gundog.lbl.gov/ dirpubs/1801_weath.pdf

CTE-DB-HE. CODIGO TECNICO DE LA EDIFICACION. DOCUMENTO BÁSICO HE AHORRO DE ENERGÍA. Available on-line on January the 4th, 2012: http://www.fomento.es/ NR/rdonlyres/B83B66E3-0BA0-4270-BEF5-84A07A4C77F8/95714/14.pdf

de León, A., Saquicela, V., Vilches, L.M., Villazón-Terrazas, B., Priyatna, F. and Corcho, O. 2010. GEOGRAPHICAL LINKED DATA: A SPANISH USE CASE. In Proceeding I-SEMANTICS '10 Proceedings of the 6th International Conference on Semantic Systems ACM New York, NY, USA ©2010. Available on-line on January the 11th, 2012 on: http://blog.semantic-web.at/wp-content/ uploads/2010/09/a36_deLeon.pdf

Dixon, A., Butler, D. and Fewkes, A. 1999. WATER SAVING POTENTIAL OF DOMESTIC WATER REUSE SYSTEMS USING GREYWATER AND RAINWATER IN COMBINATION. Water Science and Technology Vol 39 No 5 pp 25–32 © IWA Publishing. Available on-line on February the 2nd: http://www.china-sds.org/kcxfzbg/addinfomanage/lwwk/data/ kcx1104.pdf

El-Mekawy, M. and Östman, A. 2010. SEMANTIC MAPPING: AN ONTOLOGY ENGINEERING METHOD FOR INTEGRATING BUILDING MODELS IN IFC AND CITYGML. 3rd ISDE Digital Earth Summit 12-14 June, 2010, Nessebar, Bulgaria. Available on-line on January the 12th at: http://cartography-gis.com/pdf/32_El-Mekawy_Sweden_paper.pdf

Fensel, D. 2001. ONTOLOGIES: A SILVER BULLET FOR KNOWLEDGE MANAGEMENT AND. ELECTRONIC COMMERCE. Springer-Verlag, 2001. 147 pages. ISBN 3540416021

Garrido, S. and Martinez, A. 2006. MAPPING FIDE MODEL INTO IFC MODEL. eWork and eBusiness in Architecture Engineering and Construction. Pages: 95-100 ST. ISBN: 0415416221. Available on-line on January the 12th at: http://www.mendeley.com/research/mapping-fide-model-ifc-model/

Gas Natural Soluciones S.L. 2007. GUÍA TÉCNICA INSTALACIONES SOLARES TÉRMICAS.

Gröger, G., Kolbe, T.H., Czerwinski, A., Nagel, C. (Ed.). 2008. OPENGIS® CITY GEOGRAPHY MARKUP LANGUAGE (CITYGML) Encoding Standard. Open Geospatial Consortium Inc. Reference number: OGC 08-007r1. Version: 1.0.0. OpenGIS® Encoding Standard. Available on-line on January the 4th, 2012: http://www.opengeospatial.org/standards/citygml

Goyal, S. and Westenthaler, R. RDF GRAVITY (RDF GRAPH VISUALIZATION TOOL). Knowledge Information Systems Group, Salzburg Research, Austria. Available on-line on January the 11th, 2012 on: http://semweb. salzburgresearch.at/apps/rdf-gravity/user_doc.html

Guinard, D., Trifa, V., Mattern, F. and Wilde, E. 2010. FROM THE INTERNET OF THINGS TO THE WEB OF THINGS: RESOURCE-ORIENTED ARCHITECTURE AND BEST PRACTICES, , Dieter Uckelmann, Mark Harrison, Florian Michahelles (Ed.), Architecting the Internet of Things, Springer-Verlag, Heidelberg, Germany, pp. 97-129. May 2011, 978-3-642-19156-5. Available on-line on January the 11th, 2012 on: http://www.vs.inf.ethz.ch/res/papers/dguinard-fromth-2010.pdf

Heath, T., Hepp, M., and Bizer, C. (Ed.). 2009. LINKED DATA - THE STORY SO FAR. Special Issue on Linked Data, International Journal on Semantic Web and Information Systems (IJSWIS). Available on-line on January the 4th, 2012: http://www.igi-global.com/viewtitlesample.aspx?id=37496

Heim, P., Hellmann, S., Lehmann, J., Lohmann, S. and Stegemann, T. 2009. RELFINDER: REVEALING RELATIONSHIPS IN RDF KNOWLEDGE BASES. Semantic Multimedia. Lecture Notes in Computer Science Volume 5887, 2009, pp 182-187. Available on-line on January the 11th, 2012 on: http://www.jens-lehmann.org/files/2009/relfinder_samt.pdf

Heim, P., Lohmann, S. and Stegemann, T. 2010. INTERACTIVE RELATIONSHIP DISCOVERY VIA THE SEMANTIC WEB. Proceedings of the 7th Extended Semantic Web Conference (ESWC 2010), volume 6088, series LNCS, pages 303-317. Springer, Berlin/Heidelberg, 2010. Available on-line on January the 11th, 2012 on: http://www.springerlink.com/content/711420435332p748/

Hois, J., Bhatt, M. and Kutz, O. 2009. MODULAR ONTOLOGIES FOR ARCHITECTURAL DESIGN. Formal Ontologies Meet Industry. R. Ferrario and A. Oltramari (Eds.). IOS Press, 2009. doi:10.3233/978-1-60750-047-6-66. Available on-line on January the 11th, 2012 on: http://cindy.informatik.uni-bremen.de/cosy/staff/bhatt/seer/fomi09.pdf

Horridge, M. 2011. A PRACTICAL GUIDE TO BUILDING OWL ONTOLOGIES USING PROTÉGÉ 4 AND CO-ODE TOOLS. Edition 1.3. The University Of Manchester. March 24, 2011. Available on-line on January the 11th, 2012 on: http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/

Howell, I. and Batcheler, B. 2005. BUILDING INFORMATION MODELLING TWO YEARS LATER –HUGE POTENTIAL, SOME SUCCESS AND SEVERAL LIMITATIONS. Available on-line on January the 12th at: http://www.laiserin.com/features/bim/ newforma_bim.pdf

http://aemet.linkeddata.es/index.html. Last accessed February the 17th, 2012.

http://doe2.com/ Last accessed February the 17th, 2012.

http://doe2.com/download/equest/eQUESTv3-Overview.pdf. Last accessed February the 17th, 2012.

http://dublincore.org/documents/dcmi-terms/ Last accessed February the 17th, 2012.

http://gaia.lbl.gov/BDA/bda3help.pdf. Last accessed February the 17th, 2012.

http://observedchange.com/tisc/ns/ Last accessed February the 17th, 2012.

http://oegdev.dia.fi.upm.es/projects/map4rdf/ Last accessed February the 17th, 2012.

http://usa.autodesk.com/revit-architecture/ Last accessed February the 17th, 2012.

http://virtuoso.openlinksw.com/ Last accessed February the 17th, 2012.

http://wiki.dbpedia.org/About. Last accessed February the 17th, 2012.

http://www.buildingsmart-tech.org/ifc/IFC2x3/TC1/html/ifcproductextension/lexical/ Last accessed February the 17th, 2012.

http://www.elementosconstructivos.codigotecnico.org/Pages/BusquedaSC.aspx. Accessed on February the 17th, 2012.

http://www.r-project.org/about.html. Last accessed February the 17th, 2012.

http://www.sustainableenergyworld.eu/calculate-windturbine-annual-energy. Accessed on February the 17th, 2012.

http://www.visualdataweb.org/tools.php. Last accessed February the 17th, 2012.

http://www.w3.org/2003/01/geo/wgs84_pos# Last accessed February the 17th, 2012.

http://www.w3.org/DesignIssues/ Last accessed February the 17th, 2012.

http://www.w3.org/TR/2004/REC-owl-guide-20040210/ Last accessed February the 17th, 2012.

http://www.w3.org/TR/owl-time/ Last accessed February the 17th, 2012.

http://www.w3.org/TR/rdf-schema/ Last accessed February the 17th, 2012.

http://www.w3.org/TR/rdf-sparql-query/ Last accessed February the 17th, 2012.

http://www4.wiwiss.fu-berlin.de/pubby/ Last accessed February the 17th, 2012.

http://xmlns.com/foaf/spec/ Last accessed February the 17th, 2012.

Hurtera, S. and Schellschmidt, R. 2003. ATLAS OF GEOTHERMAL RESOURCES IN EUROPE. Geothermics 32(2 003) 779–787. Pergamon. Available on-line on February the 2nd: http://www.sciencedirect.com/science/article/pii/S0375650503000701

IDAE. 2009-1. ESCALA DE CALIFICACIÓN ENERGÉTICA PARA EDIFICIOS DE NUEVA CONSTRUCCIÓN. Instituto para la Diversificación y Ahorro de la Energía. Available on-line on January the 4th, 2012: http://www.minetur.gob.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/DocumentosReconocidos/OtrosDocumentos/Calificaci%C3%B3n%20energ%C3%A9tica.%20Viviendas/Escala_%20calif_energetica.pdf

IDAE. 2009-2. LIDER V1.0. Instituto para la Diversificación y Ahorro de la Energía. Ministerio de Vivienda. Available on-line on February the 2nd: http://www.codigotecnico.org/web/galerias/archivos/ManualLIDER.pdf

IDAE. 2009-3. CALENER VYP V1.0. Instituto para la Diversificación y Ahorro de la Energía. Ministerio de Vivienda. Available on-line on February the 2nd: http://www.minetur.gob.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/ProgramaCalener/CalenerVYP1/Manual_de_usuario.pdf

ITC. 2009. ENE/ENERGIA. GUÍAS DE SOSTENIBILIDAD EN LA EDIFICACIÓN RESIDENCIAL. Instituto Tecnológico de la Construcción. Generalitat Valenciana. Conselleria de Medio Ambiente, Agua, Urbanismo y Vivienda.

IVE. 2009. GUIA DE PROYECTO DEL PERFIL DE CALIDAD ESPECIFICO DE AHORRO DE ENERGIA Y SOSTENIBILIDAD. Instituto Valenciano de la Edificacion. Generalitat Valenciana. Conselleria de Medio Ambiente, Agua, Urbanismo y Vivienda.

Kim, H., Stumpf, A. and Kim, W. 2010. ANALYSIS OF AN ENERGY EFFICIENT BUILDING DESIGN THROUGH DATA MINING APPROACH. Automation in Construction 20 (2011) pp.37–43. Available on-line on January the 11th, 2012 on: http://www.sciencedirect.com/science/article/pii/S0926580510001044

Latfi, F., Lefebvre, B. and Descheneaux, C. 2007.ONTOLOGY-BASED MANAGEMENT OF THE TELEHEALTH SMART HOME, DEDICATED TO

ELDERLY IN LOSS OF COGNITIVE AUTONOMY. Proceedings of the OWLED 2007 Workshop on OWL: Experiences and Directions, Innsbruck, Austria, June 6-7, 2007. Available on-line on January the 11th, 2012 on: http://ceur-ws.org/Vol-258/paper42.pdf

Lee, J-S., Min, K-M., Lee, Y-S., Kim, J-H. and Kim, J-J. 2008. BUILDING ONTOLOGY TO IMPLEMENT THE BIM(BUILDING INFORMATION MODELLING) FOCUSED ON PRE-DESIGN STAGE. The 25th International Symposium on automation and Robotics in Construction. June, 26 – 29, 2008. Available on-line on January the 12th at: http://www.iaarc.org/publications/fulltext/ 5_sec_052_Lee_et_al_Building.pdf

Long, N. 2004. NEAR REAL-TIME WEATHER DATA ARCHIVE SimBuild 2004, IBPSA-USA National Conference Boulder, CO, August 4-6, 2004.

Machuca, M., López, M.A., Marsá Maestre, I. and Velasco, J.R. 2005. A CONTEXTUAL ONTOLOGY TO PROVIDE LOCATIONAWARE SERVICES AND INTERFACES IN SMART ENVIRONMENTS International Conference IADIS WWW/Internet 2005, October. Available on-line on January the 11th, 2012 on: 2005.http://dspace.uah.es/jspui/bitstream/10017/1263/1/iadis05-miriam.pdf

Narasimha, V., Kappara, P., Ichise, R. and Vyas, O.P. 2011. LIDDM: A DATA MINING SYSTEM FOR LINKED DATA. Linked Data on the Web LDOW2011, March 29, 2011, Hyderabad, India. Available on-line on January the 11th, 2012 on: http://ceur-ws.org/Vol-813/ldow2011-paper07.pdf

OGC 10-003r1. 2010. SUMMARY OF THE ARCHITECTURE, ENGINEERING, CONSTRUCTION, OWNER OPERATOR PHASE 1 (AECOO-1) JOINT TESTBED. buildingSMART alliance, Open Geospatial Consortium, Inc. Louis Hecht, Jr., Raj Singh (Ed.) OGC.. 010-06-04. Available on-lin on February the 2nd: https://portal.opengeospatial.org/ files/?artifact_id=37223

Papamichael, K. 1999. APPLICATION OF INFORMATION TECHNOLOGIES IN BUILDING DESIGN DECISIONS. Building Research & Information, V.27(1):20-34, January/February 1999. Available on-line on February the 2nd: http://gaia.lbl.gov/BDA/documents/bri99.pdf

Papamichael, K., Chauvet, H., LaPorta, J. and Dandridge, R. 1999. PRODUCT MODELLING FOR COMPUTER-AIDED DECISION-MAKING. Automation in Construction 8 (1999) 339-350. The Netherlands. Elsevier Science B.V. 1999. Available on-line on February the 2nd: Product modelling for computer-aided decision-making

RD 47/2007. 2007. REAL DECRETO DE 19 DE ENERO, POR EL QUE SE APRUEBA EL PROCEDIMIENTO BÁSICO PARA LA CERTIFICACIÓN DE EFICIENCIA ENERGÉTICA DE EDIFICIOS DE NUEVA CONSTRUCCIÓN. BOE núm. 27 Miércoles 31 enero 2007 p.4499. Available on-line on January the 4th, 2012: http://www.boe.es/boe/dias/ 2007/01/31/pdfs/A04499-04507.pdf

RETScreen. 2005. CLEAN ENERGY PROJECT ANALYSIS. RETSCREEN ENGINEERING & CASES TEXTBOOK. Third Edition. . Minister of Natural Resources Canada 2001-2005. Available on-line on February the 2nd: http://www.retscreen. net/download.php/ang/532/0/Textbook.pdf

Schell, D., McKee, L. and Buehler, K. 2000. GEODATA INTEROPERABILITY – A KEY NII REQUIREMENT. An Open GIS Consortium (OGC) White Paper. submitted to the NII 2000 Steering Committee of the Computer Science and Telecommunications Board of the National Research Council. Available on-line on January the 4th, 2012: http://portal.opengeospatial.org/files/?artifact_id= 6200&version=1&format=htm

SIG 3D. 2006. CANDIDATE OPENGIS® CITYGML IMPLEMENTATION SPECIFICATION (CITY GEOGRAPHY MARKUP LANGUAGE). Special Interest Group 3D. Open Geospatial Consortium Inc. 2006-07-28. OGC 06-057r1. Version: 0.3.0. Gerhard Gröger, Thomas H. Kolbe, Angela Czerwinski (Ed.).

Singh, M.K., Mahapatra, S. and Atreya, S.K. 2009. BIOCLIMATISM AND VERNACULAR ARCHITECTURE OF NORTH-EAST INDIA. Building and Environment 44 (2009) 878–888. Available on-line on February the 2nd: http://www. sciencedirect.com/science/article/pii/S0360132308001522

Suri, M. and Hofierka, J. 2004. A NEW GIS-BASED SOLAR RADIATION MODEL AND ITS APPLICATION TO PHOTOVOLTAIC ASSESSMENTS. Transactions in GIS, 8(2) pp.175–190

Suri, M., Huld, T.A., Dunlop, E.D. and Ossenbrink, H.A. 2007. POTENTIAL OF SOLAR ELECTRICITY GENERATION IN THE EUROPEAN UNION MEMBER STATES AND CANDIDATE COUNTRIES. Solar Energy. Volume 81, Issue 10, October 2007, Pages 1295–1305. Available on-line on February the 2nd: http://www.sciencedirect.com/science/article/pii/S0038092X07000229

Tudorache, T., Vendetti, J. and Noy, N.F. 2008. WEB-PROTEGE: A LIGHTWEIGHT OWL ONTOLOGY EDITOR FOR THE WEB. OWLED 2008 OWL: Experiences and Directions. Fifth International Workshop. Karlsruhe, Germany. October 26-27, 2008. Available on-line on January the 11th, 2012 on: http://ceur-ws.org/Vol-432/owled2008eu_submission_40.pdf

Voivontas, D., Tsiligiridis, G. and Assimacopoulos, D. 1998. SOLAR POTENTIAL FORWATER HEATING EXPLORED BY GIS. Solar Energy Vol. 62, No. 6, pp. 419–427, 1998 © 1998 Elsevier Science Ltd. Available on-line on February the 2nd: http://environ.chemeng.ntua.gr/en/Uploads/Doc/Papers/Renewable%20Energy/1998_Solar%20potential%20for%20water%20heating%20explored%20by%20GIS.pdf

Wang, X.H., Zhang, D.Q., Gu, T. and Keng, H. 2004.ONTOLOGY BASED CONTEXT MODELLING AND REASONING USING OWL. Proceedings of the Second IEEE Annual Conference on Pervasive Computing and Communications Workshops (PERCOMW'04) 0-7695-2106-1/04.

Watson, R.T., Zinyowera, M.C. and Moss, R.H. (Ed.). 1996. TECHNOLOGIES, POLICIES AND MEASURES FOR MITIGATING CLIMATE CHANGE. IPCC Technical Paper I. Available on-line on January the 4th, 2012: http://www.ipcc.ch/pdf/technical-papers/paper-I-en.pdf

Willighagen, E. 2011. RRDF - SUPPORT FOR THE RESOURCE DESCRIPTION FRAMEWORK. Available on-line on January the 11th, 2012 on: http://cran.r-project.org/web/packages/rrdf/rrdf.pdf

Xu, J., Lee, Y-H., Tsai, W-T., Li, W., Son, Y-S., Park, J-H. and Moon, K-D. 2009. ONTOLOGY-BASED SMART HOME SOLUTION AND SERVICE COMPOSITION. 2009 International Conferences on Embedded Software and Systems. IEEE. Available on-line on January the 11th, 2012 on: http://www.es.sdu.edu.cn/project/doc/papers/icess09-papers/13-2.pdf

ANNEXES

ANNEX A. RDF LODBLESS INSTANCE


```
<?xml version="1.0" encoding="UTF-8"?>

<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:geo="http://www.w3.org/2003/01/geo/wgs84_pos#"
xmlns:dcterm="http://purl.org/dc/terms/"
xmlns:ene="http://www.anasanhue.hostzi.com/joomla/index.php/en/projects/information-
technologies/92-lodblessene#"
xmlns:bui="http://www.anasanhue.hostzi.com/joomla/index.php/en/projects/information-
technologies/92-lodblessbui#"
xmlns:lodbless="http://pad.ifgi.de/"
xmlns:foaf="http://xmlns.com/foaf/spec/#"
xmlns:ifc4="http://buildingsmart-tech.org/ifc/IFC2x4/rc1/html/ifcsharedbldgelements/lexical/"
xmlns:ifc3_2="http://www.buildingsmart-
tech.org/ifc/IFC2x3/TC1/html/ifcproductextension/lexical/"
xmlns:ifc2_3="http://www.buildingsmart-
tech.org/ifc/IFC2x3/TC1/html/ifcsharedbldgelements/lexical/">
    <rdf:Description rdf:about="lodbless:gandia74">
        <title xmlns="dcterm:">building_example</title>
        <type xmlns="rdf:" rdf:resource="ifc3_2:ifcbuilding"></type>
        <locatedAt xmlns="http://observedchange.com/tisc/ns#"
        rdf:resource="lodbless:gandia74_loc"></locatedAt>
        <areasize xmlns="http://observedchange.com/tisc/ns#">70</areasize>
        <consumption xmlns="ene:"
        rdf:resource="lodbless:gandia74_ene"></consumption>
        <container xmlns="rdfs:" rdf:resource="lodbless:gandia74_i"></container>
        <container xmlns="rdfs:" rdf:resource="lodbless:gandia74_j"></container>
        <energyPerformanceClass xmlns="ene:"
        rdf:resource="lodbless:ClassB"></energyPerformanceClass>
    </rdf:Description>
    <rdf:Description rdf:about="http://pad.ifgi.de/gandia74_loc">
        <term_based_near xmlns="foaf:"
        rdf:resource="http://geo.linkeddata.es/page/resource/Municipio/Valencia"></ter
        m_based_near>
```

```
<term_based_near xmlns="foaf:"
rdf:resource="http://sws.geonames.org/2509954"></term_based_near>
<term_based_near xmlns="foaf:"
rdf:resource="https://www1.sedecatastro.gob.es/Cartografia/MostrarParcelas.asp
x?del=46&amp;mapa=5,242&amp;coorx=725243.2218675179&amp;coory=437233
0.4878048785&amp;huso=30"></term_based_near>
<lat xmlns="http://www.w3.org/2003/01/geo/wgs84_pos#">39.47</lat>
<long xmlns="http://www.w3.org/2003/01/geo/wgs84_pos#">-0.377</long>
<alt xmlns="http://www.w3.org/2003/01/geo/wgs84_pos#">18</alt>
<weatherStation xmlns="lodbless:loc#"
rdf:resource="http://aemet.linkeddata.es/page/resource/WeatherStation/id08285
"></weatherStation>
<database xmlns="lodbless:loc#"
rdf:resource="http://re.jrc.ec.europa.eu/pvgis/solres/images/big/g13/gs13_opt.pn
g"></database>
</rdf:Description>
<rdf:Description rdf:about="lodbless:gandia74_ene">
<type xmlns="rdf:" rdf:resource="ene:BuiEne"></type>
<eleCon xmlns="ene:">2292</eleCon>
<eleP xmlns="ene:">0,206</eleP>
<eleConP xmlns="ene:">474</eleConP>
<eleConMonth xmlns="ene:">191</eleConMonth>
<gasCon xmlns="ene:">16470</gasCon>
<gasP xmlns="ene:">0,064</gasP>
<gasConP xmlns="ene:">1050</gasConP>
<gasConMonth xmlns="ene:">1372</gasConMonth>
<waterCon xmlns="ene:">54</waterCon>
<waterP xmlns="ene:">2,444</waterP>
<waterConP xmlns="ene:">132</waterConP>
<waterConMonth xmlns="ene:">4,5</waterConMonth>
<res xmlns="ene:">N</res>
<resPVSystem xmlns="ene:" rdf:resource="lodbless:PV_101"></resPVSystem>
<resPVInv xmlns="ene:">9600</resPVInv>
<resPVGen xmlns="ene:">2310</resPVGen>
<resPVGenMonth xmlns="ene:">193</resPVGenMonth>
```

```
</rdf:Description>
<rdf:Description rdf:about="lodbless:gandia74_i">
	<type xmlns="rdf:" rdf:resource="ifc3_2:ifcspace"></type>
	<areasize xmlns="http://observedchange.com/tisc/ns#">30</areasize>
	<use xmlns="dbpprop:">LivingRoom</use>
	<function xmlns="bui:">interior</function>
	<hasNeighbor xmlns="bui:" rdf:resource="lodbless:gandia74_j"></hasNeighbor>
	<boundedBy xmlns="bui:" rdf:resource="lodbless:gandia74_i,j"></boundedBy>
	<eastOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_j"></eastOf>
	<dcterm:isPartOf rdf:resource="lodbless:gandia74"/>
</rdf:Description>
<rdf:Description rdf:about="lodbless:gandia74_j">
	<type xmlns="rdf:" rdf:resource="ifc3_2:ifcspace"></type>
	<areasize xmlns="http://observedchange.com/tisc/ns#">40</areasize>
	<use xmlns="dbpprop:">Garden</use>
	<function xmlns="bui:">exterior</function>
	<hasNeighbor xmlns="bui:" rdf:resource="lodbless:gandia74_i"></hasNeighbor>
	<westOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_i"></westOf>
	<dcterm:isPartOf rdf:resource="lodbless:gandia74"/>
</rdf:Description>
<rdf:Description rdf:about="lodbless:gandia74_i,j">
	<type xmlns="rdf:" rdf:resource="ifc3_2:ifcbuildingelement"></type>
	<type xmlns="rdf:" rdf:resource="ifc2_3:ifcwall"></type>
	<areasize xmlns="http://observedchange.com/tisc/ns#">88</areasize>
	<function xmlns="bui:">EVE_fac?ade</function>
	<eastOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_i"></eastOf>
	<westOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_i"></westOf>
	<southOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_i"></southOf>
	<northOf xmlns="http://observedchange.com/tisc/ns#"
	rdf:resource="lodbless:gandia74_i"></northOf>
```

```
            <hasOpening xmlns="bui:" rdf:resource="lodbless:gandia74_i,j,k"></hasOpening>
            <hasSystem xmlns="bui:">Fide_solConst_2027</hasSystem>
            <limitKForWalls xmlns="bui:">0,82</limitKForWalls>
            <dcterm:isPartOf rdf:resource="lodbless:gandia74_i"/>
      </rdf:Description>
      <rdf:Description rdf:about="lodbless:gandia74_i,j,k">
            <type xmlns="rdf:" rdf:resource="ifc4:ifcwindow"></type>
            <areasize xmlns="http://observedchange.com/tisc/ns#">1</areasize>
            <hasSystem xmlns="bui:">Fide_solConst_5789</hasSystem>
            <limitKForWindowsN xmlns="bui:">3</limitKForWindowsN>
            <limitKForWindowsEW xmlns="bui:">4</limitKForWindowsEW>
            <limitKForWindowsS xmlns="bui:">5,6</limitKForWindowsS>
            <limitFForWindowsN xmlns="bui:">-</limitFForWindowsN>
            <limitFForWindowsEW xmlns="bui:">0,45</limitFForWindowsEW>
            <limitFForWindowsS xmlns="bui:">-</limitFForWindowsS>
            <dcterm:isPartOf rdf:resource="lodbless:gandia74_i,j"/>
      </rdf:Description>
</rdf:RDF>
```

ANNEX B. SPARQL QUERIES

Queries performed on AEMET endpoint http://aemet.linkeddata.es/sparql. First query is for finding which weather station is the closest to our building location, within a 2 hundredth grades north-south, east-west bounding box:

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>
SELECT ?weatherStation, ?lat, ?long, ?alt
WHERE {
?weatherStation geo:location ?location .
?location geo:lat ?lat .
?location geo:long ?long .
?location geo:alt ?alt .
FILTER ( xsd:double(?lat) < xsd:double("39.49") ) .
FILTER ( xsd:double(?lat) > xsd:double("39.45") ) .
FILTER ( xsd:double(?long) < xsd:double("-0.357") ) .
FILTER ( xsd:double(?long) > xsd:double("-0.397") ) . }
```

Result:

weatherStation	lat	long	alt
http://aemet.linkeddata.es/resource/WeatherStation/id08285	39.480555555600	-0.366388888889	11

Table B 1.- Query results from weather station within bounding box

Next query looks for weather observations needed for the clime zone classification:

```
PREFIX aemetonto: <http://aemet.linkeddata.es/ontology/>
PREFIX aemetWeatherStation: <http://aemet.linkeddata.es/resource/WeatherStation/>
PREFIX aemetTemperatureAmbientProperty:
<http://aemet.linkeddata.es/resource/TemperatureAmbientProperty/>
PREFIX ssn: <http://purl.oclc.org/NET/ssnx/ssn#>
PREFIX time: <http://www.w3.org/2006/time#>
SELECT ?year, ?month, ?day, ?hour, ?valueOfObservedData
WHERE {
?observation aemetonto:valueOfObservedData ?valueOfObservedData.
?observation ssn:observedBy aemetWeatherStation:id08285 .
?observation ssn:observedProperty aemetTemperatureAmbientProperty:TA .
?observation aemetonto:observedInInterval ?observedInterval .
?observedInterval time:hasBeginning ?instant .
?instant time:inDateTime ?dateTimeDescription .
?dateTimeDescription time:year ?year .
?dateTimeDescription time:month ?month .
?dateTimeDescription time:day ?day .
?dateTimeDescription time:hour ?hour . }
ORDER BY ?year ?month ?day ?hour
```

Result:

year	month	day	hour	value…
2011	5	26	19	25.4
2011	9	5	23	24.4
2011	9	6	0	24.2
2011	9	6	0	24
2011	9	6	0	23.8
2011	9	6	0	24.2
2011	9	6	0	23.7
2011	9	6	0	24.3
2011	9	6	1	23.7
2011	9	6	1	23.6
2011	9	6	1	23.5
2011	9	6	1	23.6
2011	9	6	1	23.5
2011	9	6	1	23.8
2011	9	6	2	23
2011	9	6	2	23.2
2011	9	6	2	23.4
2011	9	6	2	23
2011	9	6	2	23.3
2011	9	6	2	22.9
2011	9	6	3	22.6
2011	9	6	3	22.7
2011	9	6	3	22.6
2011	9	6	3	22.7
2011	9	6	3	22.7
2011	9	6	3	22.7
2011	9	6	4	22.3
2011	9	6	4	22.3
2011	9	6	4	22.4
2011	9	6	4	22.3
2011	9	6	4	22.2
2011	9	6	4	22.5
2011	9	6	5	21.9
2011	9	6	5	21.9
2011	9	6	5	21.9
2011	9	6	5	21.8
2011	9	6	5	22
2011	9	6	5	22
2011	9	6	6	22.1
2011	9	6	6	22.3
2011	9	6	6	22.1
2011	9	6	6	21.9
2011	9	6	6	22.4
2011	9	6	6	22
2011	9	6	7	23.9
2011	9	6	7	23.5
2011	9	6	7	24.4
2011	9	6	7	23.1
2011	9	6	7	22.6
2011	9	6	7	22.8
2011	9	6	8	26.1
2011	9	6	8	24.7
2011	9	6	8	25.5
2011	9	6	8	25.9
2011	9	6	8	26.7
2011	9	6	8	25.1
2011	9	12	23	23.6
2011	9	13	0	23.6
2011	9	13	0	23.3
2011	9	13	0	23.2
2011	9	13	0	23.7
2011	9	13	0	23.4
2011	9	13	0	23.6
2011	9	13	1	23.2
2011	9	13	1	23.1
2011	9	13	1	22.9
2011	9	13	1	22.8
2011	9	13	1	23
2011	9	13	1	23.1
2011	9	13	2	22
2011	9	13	2	22.7
2011	9	13	2	22.1
2011	9	13	2	22.4
2011	9	13	2	22.3
2011	9	13	2	22.6
2011	9	13	3	21.7
2011	9	13	3	21.5
2011	9	13	3	21.7
2011	9	13	3	21.5
2011	9	13	3	21.6
2011	9	13	3	21.7
2011	9	13	4	21.6
2011	9	13	4	21.7
2011	9	13	4	21.5
2011	9	13	4	21.5
2011	9	13	4	21.7
2011	9	13	4	21.4
2011	9	13	5	21.5
2011	9	13	5	21.4
2011	9	13	5	21.1
2011	9	13	5	21.5
2011	9	13	5	21
2011	9	13	5	21.2
2011	9	13	6	22.1
2011	9	13	6	21
2011	9	13	6	22
2011	9	13	6	21.3
2011	9	13	6	21.3
2011	9	13	6	21.4
2011	9	13	7	22.1
2011	9	13	7	23.5

2011	9	13	7	24.3
2011	9	13	7	23.1
2011	9	13	7	23.3
2011	9	13	7	22.7
2011	9	13	8	25.6
2011	9	13	8	24.9
2011	9	13	8	26.2
2011	9	13	8	26.7
2011	9	13	8	25.7
2011	9	13	8	27.2
2011	9	13	9	29.4
2011	9	13	9	27.3
2011	9	13	9	28.8
2011	9	13	9	29.1
2011	9	13	9	28.7
2011	9	13	9	27.8
2011	9	13	10	29.4
2011	9	13	10	28.4
2011	9	13	10	29.1
2011	9	13	10	29
2011	9	13	10	29
2011	9	13	10	28.7
2011	9	13	11	28.5
2011	9	13	11	28.7
2011	9	13	11	29.3
2011	9	13	11	28.2
2011	9	13	11	28.2
2011	9	13	11	28.7
2011	9	13	12	28.2
2011	9	13	12	28.5
2011	9	13	12	27.9
2011	9	13	12	28.3
2011	9	13	12	28.6
2011	9	13	12	28.1
2011	9	13	13	28.5
2011	9	13	13	27.8
2011	9	13	13	28.2
2011	9	13	13	28.2
2011	9	13	13	28.1
2011	9	13	13	27.6
2011	9	13	14	27.9
2011	9	13	14	27.5
2011	9	13	14	27.2
2011	9	13	14	27.1
2011	9	13	14	27.7
2011	9	13	14	27.7
2011	9	13	15	27.4
2011	9	13	15	26.9
2011	9	13	15	26.9
2011	9	13	15	27.1
2011	9	13	15	27
2011	9	13	15	27.6
2011	9	13	16	26.6
2011	9	13	16	26.9
2011	9	13	16	26.8
2011	9	13	16	26.5
2011	9	13	16	26.6
2011	9	13	16	26.5
2011	9	13	17	26.5
2011	9	13	17	26.2
2011	9	13	17	26.3
2011	9	13	17	26.4
2011	9	13	17	26.6
2011	9	13	17	26.4
2011	9	13	18	25.9
2011	9	13	18	26
2011	9	13	18	25.8
2011	9	13	18	26
2011	9	13	18	26
2011	9	13	18	26.1
2011	9	13	19	25.4
2011	9	13	19	25.3
2011	9	13	19	25.6
2011	9	13	19	25.5
2011	9	13	19	25.6
2011	9	13	19	25.6
2011	9	13	20	24.8
2011	9	13	20	25
2011	9	13	20	24.7
2011	9	13	20	24.9
2011	9	13	20	25.2
2011	9	13	20	25.2
2011	9	13	21	24.3
2011	9	13	21	24
2011	9	13	21	24.1
2011	9	13	21	24.6
2011	9	13	21	24.5
2011	9	13	21	24.5
2011	9	13	22	23.7
2011	9	13	22	23.8
2011	9	13	22	23.4
2011	9	13	22	23.7
2011	9	13	22	23.6
2011	9	13	22	23.5
2011	9	13	23	23.2
2011	9	13	23	23.3
2011	9	13	23	22.9
2011	9	13	23	23
2011	9	13	23	23.1
2011	9	13	23	22.8
2011	9	14	0	22.4
2011	9	14	0	22.7
2011	9	14	0	22.2
2011	9	14	0	22.4
2011	9	14	1	21.9
2011	9	14	1	21.9
2011	9	14	1	22.1
2011	9	14	1	21.7

2011	9	14	1	22
2011	9	14	1	21.7
2011	9	14	2	21.6
2011	9	14	2	21.5
2011	9	14	2	21.4
2011	9	14	2	21.5
2011	9	14	2	21.5
2011	9	14	2	21.5
2011	9	14	3	21.5
2011	9	14	3	21.3
2011	9	14	3	21.4
2011	9	14	3	21.4
2011	9	14	3	21.3
2011	9	14	4	21.8
2011	9	14	4	21.8
2011	9	14	4	21.9
2011	9	14	4	21.6
2011	9	14	4	21.9
2011	9	14	5	21.4
2011	9	14	5	21.4
2011	9	14	5	21.6
2011	9	14	5	21.5
2011	9	14	5	21.7
2011	9	14	5	21.6
2011	9	14	6	21.6
2011	9	14	6	21.4
2011	9	14	6	21.3
2011	9	14	6	21.3
2011	9	14	6	21.4
2011	9	14	6	21.9
2011	9	14	7	23.2
2011	9	14	7	22.9
2011	9	14	7	23.6
2011	9	14	8	26.3
2011	9	14	8	25.4
2011	9	14	8	24.4
2011	9	14	8	25.7
2011	9	14	8	25.1
2011	9	14	9	27.4
2011	9	14	9	28.3
2011	9	14	9	27.2
2011	9	14	9	28.8
2011	9	14	10	29.1
2011	9	14	10	29.3
2011	9	14	10	28.9
2011	9	14	11	28.5
2011	9	14	11	29
2011	9	14	11	28.9
2011	9	14	11	28.4
2011	9	14	11	28.9
2011	9	14	11	28.8
2011	9	14	12	30.1
2011	9	14	12	28.9
2011	9	14	12	28.1

2011	9	14	12	28.8
2011	9	14	12	28
2011	9	14	13	28.7
2011	9	14	13	28.2
2011	9	14	13	28.2
2011	9	14	13	28.5
2011	9	14	14	27.3
2011	9	14	14	26.8
2011	9	14	14	28.5
2011	9	14	14	28.3
2011	9	14	14	27
2011	9	14	14	28.7
2011	9	14	15	26.8
2011	9	14	15	26.8
2011	9	14	15	26.7
2011	9	14	15	26.6
2011	9	14	15	26.8
2011	9	14	16	26.5
2011	9	14	16	26.4
2011	9	14	16	26.3
2011	9	14	16	26.4
2011	9	14	16	26.2
2011	9	14	16	26.9
2011	9	14	17	26.4
2011	9	14	17	26.2
2011	9	14	17	26.4
2011	9	14	17	26
2011	9	14	18	25.7
2011	9	14	18	25.6
2011	9	14	18	25.9
2011	9	14	18	25.9
2011	9	14	18	25.7
2011	9	14	19	25.5
2011	9	14	19	25.3
2011	9	14	19	25.3
2011	9	14	19	25.4
2011	9	14	19	25.5
2011	9	14	19	25.3
2011	9	14	20	25
2011	9	14	20	25.2
2011	9	14	20	24.8
2011	9	14	20	25.2
2011	9	14	20	25.2
2011	9	14	21	24.3
2011	9	14	21	24.1
2011	9	14	21	24.7
2011	9	14	21	24.1
2011	9	14	21	24.3
2011	9	14	21	24.2
2011	9	14	22	23.5
2011	9	14	22	23.8
2011	9	14	22	23.6
2011	9	14	22	23.9
2011	9	14	23	23.2

2011	9	15	0	23.1
2011	9	15	0	23.1
2011	9	15	0	23.1
2011	9	15	0	22.9
2011	9	15	0	22.8
2011	9	15	0	23.1
2011	9	15	1	22.6
2011	9	15	1	22.6
2011	9	15	1	22.5
2011	9	15	1	22.5
2011	9	15	1	22.8
2011	9	15	1	22.7
2011	9	15	2	22.4
2011	9	15	2	22.1
2011	9	15	2	22.3
2011	9	15	2	22.4
2011	9	15	2	22.2
2011	9	15	2	21.9
2011	9	15	3	21.6
2011	9	15	3	21.7
2011	9	15	3	21.5
2011	9	15	3	21.9
2011	9	15	3	21.6
2011	9	15	3	21.5
2011	9	15	4	21.5
2011	9	15	4	21.5
2011	9	15	4	21.3
2011	9	15	4	21.2
2011	9	15	4	21.1
2011	9	15	4	21.4
2011	9	15	5	21
2011	9	15	5	21
2011	9	15	5	21.1
2011	9	15	5	21.1
2011	9	15	5	21.1
2011	9	15	5	21.2
2011	9	15	6	21.9
2011	9	15	6	21.1
2011	9	15	6	21.2
2011	9	15	6	21.1
2011	9	15	6	21.6
2011	9	15	6	21.4
2011	9	15	7	23.3
2011	9	15	7	22.8
2011	9	15	7	22.5
2011	9	15	7	23.8
2011	9	15	7	23.9
2011	9	15	7	23
2011	9	15	8	25.3
2011	9	15	8	25.8
2011	9	15	8	24.4
2011	9	15	8	26.1
2011	9	15	8	26.5
2011	9	15	8	24.9
2011	9	15	9	27.3
2011	9	15	9	28.3
2011	9	15	9	26.8
2011	9	15	9	28.5
2011	9	15	9	28.8
2011	9	15	9	27.9
2011	9	15	10	30.1
2011	9	15	10	29.6
2011	9	15	10	29
2011	9	15	10	30.2
2011	9	15	10	30.2
2011	9	15	10	30.4
2011	9	15	11	29.4
2011	9	15	11	29.8
2011	9	15	11	29.6
2011	9	15	11	29.6
2011	9	15	11	29.3
2011	9	15	11	29.5
2011	9	15	12	29.7
2011	9	15	12	29.3
2011	9	15	12	29
2011	9	15	12	29.8
2011	9	15	12	29.2
2011	9	15	12	29.9
2011	9	15	13	29.4
2011	9	15	13	28.8
2011	9	15	13	29.1
2011	9	15	13	29.4
2011	9	15	13	29.3
2011	9	15	13	29.2
2011	9	15	14	28.8
2011	9	15	14	28.3
2011	9	15	14	28.6
2011	9	15	14	27.9
2011	9	15	14	28.4
2011	9	15	14	29
2011	9	15	15	28.3
2011	9	15	15	28.4
2011	9	15	15	27.7
2011	9	15	15	27.6
2011	9	15	15	28.4
2011	9	15	15	27.8
2011	9	15	16	27.2
2011	9	15	16	27.6
2011	9	15	16	27.8
2011	9	15	16	27.5
2011	9	15	16	27.1
2011	9	15	16	27.1
2011	9	15	17	26.3
2011	9	15	17	26.6
2011	9	15	17	26.6
2011	9	15	17	26.7
2011	9	15	17	26.5
2011	9	15	17	26.8

2011	9	15	18	26.3
2011	9	15	18	26.2
2011	9	15	18	26.1
2011	9	15	18	26.3
2011	9	15	18	26
2011	9	15	18	26
2011	9	15	19	25.7
2011	9	15	19	25.7
2011	9	15	19	25.8
2011	9	15	19	25.7
2011	9	15	19	25.8
2011	9	15	19	25.7
2011	9	15	20	25.4
2011	9	15	20	25.3
2011	9	15	20	25.2
2011	9	15	20	25.3
2011	9	15	20	25.2
2011	9	15	20	25.3
2011	9	15	21	24.4
2011	9	15	21	24.4
2011	9	15	21	24.9
2011	9	15	21	24.5
2011	9	15	21	24.7
2011	9	15	21	24.7
2011	9	15	22	23.9
2011	9	15	22	24
2011	9	15	22	24.3
2011	9	15	22	24
2011	9	15	22	24.4
2011	9	15	22	24.2
2011	9	17	2	22.5
2011	9	17	3	22.1
2011	9	17	6	21.2
2011	9	17	6	21.3
2011	9	17	6	21.8
2011	9	17	7	22
2011	9	17	8	25.8
2011	9	17	8	23.6
2011	9	17	10	26.5
2011	9	17	11	28
2011	9	17	12	27.6
2011	9	17	16	26.3
2011	9	17	16	26.4
2011	9	17	16	26.4
2011	9	17	20	24.7
2011	9	17	20	24.7
2011	9	17	21	23.9
2011	9	17	23	23.2
2011	9	18	0	22.6
2011	9	18	0	23
2011	9	18	0	22.8
2011	9	18	0	22.6
2011	9	18	0	22.8
2011	9	18	0	23

2011	9	18	1	22.1
2011	9	18	1	22.2
2011	9	18	1	22.2
2011	9	18	1	22.5
2011	9	18	1	22.4
2011	9	18	1	22.5
2011	9	18	2	22
2011	9	18	2	22.1
2011	9	18	2	22
2011	9	18	2	22
2011	9	18	2	22.1
2011	9	18	2	22
2011	9	18	3	21.5
2011	9	18	3	21.4
2011	9	18	3	21.7
2011	9	18	3	21.8
2011	9	18	3	21.9
2011	9	18	3	21.8
2011	9	18	4	20.9
2011	9	18	4	21.3
2011	9	18	4	20.7
2011	9	18	4	20.8
2011	9	18	4	21.2
2011	9	18	4	21
2011	9	18	5	20.5
2011	9	18	5	20.5
2011	9	18	5	20.4
2011	9	18	5	20.5
2011	9	18	5	20.5
2011	9	18	5	20.4
2011	9	18	6	21.2
2011	9	18	6	21
2011	9	18	6	20.8
2011	9	18	6	20.6
2011	9	18	6	21
2011	9	18	6	20.4
2011	9	18	7	23.1
2011	9	18	7	23.5
2011	9	18	7	22
2011	9	18	7	22.6
2011	9	18	7	21.4
2011	9	18	7	21.6
2011	9	18	8	23.8
2011	9	18	8	24.3
2011	9	18	8	25.7
2011	9	18	8	25.2
2011	9	18	8	24.6
2011	9	18	8	26.2
…	…	…	…	…

Table B 2.- Query results from temperature observations by selected weather station

ANNEX C. R CODE PROCESSES

For the first process we should find which sensor having available the weather data needed are closest to our location.

First we query our building location. Then, a buffer expressed as a range of validity (4 hundredths of a degree -2 up and 2 down- from the location of the building) for the values of the coordinates of the weather stations is performed. This operation is repeated until the first weather station is found. Then the extraction of the data will be performed. The only input data by the user is then the location. The output is a collection of climate data.

As an example, part of the R code for this process can be consulted below:

```
> #loading package rrdf - support for the Resource Description Framework
> library(rrdf)
Loading required package: rJava
Loading required package: rrdflibs
Mensajes de aviso perdidos
1: package 'rrdf' was built under R version 2.12.2
2: package 'rJava' was built under R version 2.12.2
3: package 'rrdflibs' was built under R version 2.12.2

> #loading local rdf file where building is modeled
> m1 = load.rdf("C:/Datos/Ana/erasmus/pfm/datos/test/lodbless_gandia_74_b.rdf")

> #getting its coordinates
> sparql.rdf(m1, paste(
+ "select ?lat ?long ?alt {
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat.
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#long> ?long.
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#alt> ?alt.
+ }"))
     lat     long     alt
[1,] "39.47" "-0.377" "18"

> #defining Building lat
> Blat = sparql.rdf(m1, paste(
+ "select ?lat {
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat.}"))
> Blat
     lat
[1,] "39.47"

> #defining Building long
> Blong = sparql.rdf(m1, paste(
+ "select ?long {
```

```
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#long>
?long.}"))
> Blong
    long
[1,] "-0.377"

> #defining Building alt
> Balt = sparql.rdf(m1, paste(
+ "select ?alt {
+ <http://pad.ifgi.de/gandia74_loc> <http://www.w3.org/2003/01/geo/wgs84_pos#alt> ?alt.}"))
> Balt
    alt
[1,] "18"

> #next we define a bounding window around building coordinates for searching the closest
weather station

> #defining lat upper limit for weather station coordinates
> Blatup = as.numeric(Blat)+0.02
> Blatup
[1] 39.49

> #defining lat lower limit for weather station coordinates
> Blatdown = as.numeric(Blat)-0.02
> Blatdown
[1] 39.45

> #defining long upper limit for weather station coordinates
> Blongup = as.numeric(Blong)+0.02
> Blongup
[1] -0.357

> #defining long lower limit for weather station coordinates
> Blongdown = as.numeric(Blong)-0.02
> Blongdown
[1] -0.397

> #searching for weather stations whose coordinates are within the limits previously defined
> Wstation = sparql.remote("http://aemet.linkeddata.es/sparql",
+ paste(
+ "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
+ SELECT ?weatherStation {
+ ?weatherStation <http://www.w3.org/2003/01/geo/wgs84_pos#location> ?location .
+ ?location <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ?lat .
+ ?location <http://www.w3.org/2003/01/geo/wgs84_pos#long> ?long .
+ ?location <http://www.w3.org/2003/01/geo/wgs84_pos#alt> ?alt .
+ FILTER (xsd:double(?lat) <= 39.49) .
+ FILTER (xsd:double(?lat) >= 39.45) .
+ FILTER (xsd:double(?long) <= -0.357) .
+ FILTER (xsd:double(?long) >= -0.397) .
+ }"))
> Wstation
    weatherStation
```

```
[1,] http://aemet.linkeddata.es/resource/WeatherStation/id08285

> #extracting climate data needed for climeta zone classification
> Cdata = sparql.remote("http://aemet.linkeddata.es/sparql",
+ paste(
+ "PREFIX aemetonto: <http://aemet.linkeddata.es/ontology/>
+ PREFIX aemetWeatherStation: <http://aemet.linkeddata.es/resource/WeatherStation/>
+ PREFIX aemetTemperatureAmbientProperty:
<http://aemet.linkeddata.es/resource/TemperatureAmbientProperty/>
+ PREFIX ssn: <http://purl.oclc.org/NET/ssnx/ssn#>
+ PREFIX time: <http://www.w3.org/2006/time#>
+ SELECT ?year ?month ?day ?hour ?valueOfObservedData {
+ ?observation aemetonto:valueOfObservedData ?valueOfObservedData.
+ ?observation ssn:observedBy aemetWeatherStation:id08285 .
+ ?observation ssn:observedProperty aemetTemperatureAmbientProperty:TA .
+ ?observation aemetonto:observedInInterval ?observedInterval .
+ ?observedInterval time:hasBeginning ?instant .
+ ?instant time:inDateTime ?dateTimeDescription .
+ ?dateTimeDescription time:year ?year .
+ ?dateTimeDescription time:month ?month .
+ ?dateTimeDescription time:day ?day .
+ ?dateTimeDescription time:hour ?hour .
+ }
+ order by ?year ?month ?day ?hour
+ "))
> Cdata
    valueOfObservedData day                              year                              month
 [1,]   "25.4"                              "26^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"5^^http://www.w3.org/2001/XMLSchema#int"
 [2,]   "24.4"                              "5^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [3,]   "24.2"                              "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [4,]   "24"                                "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [5,]   "23.8"                              "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [6,]   "24.2"                              "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [7,]   "23.7"                              "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
 [8,]   "24.3"                              "6^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"

[…]
```

```
[608,]    "22"                                 "18^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
[609,]    "22.2"                               "18^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
[610,]    "22.4"                               "18^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
[611,]    "22.3"                               "18^^http://www.w3.org/2001/XMLSchema#int"
"2011^^http://www.w3.org/2001/XMLSchema#int"
"9^^http://www.w3.org/2001/XMLSchema#int"
      hour
  [1,] "19^^http://www.w3.org/2001/XMLSchema#int"
  [2,] "23^^http://www.w3.org/2001/XMLSchema#int"
  [3,] "0^^http://www.w3.org/2001/XMLSchema#int"
  [4,] "0^^http://www.w3.org/2001/XMLSchema#int"
  [5,] "0^^http://www.w3.org/2001/XMLSchema#int"
  [6,] "0^^http://www.w3.org/2001/XMLSchema#int"
  [7,] "0^^http://www.w3.org/2001/XMLSchema#int"
  [8,] "0^^http://www.w3.org/2001/XMLSchema#int"

[…]

[608,] "22^^http://www.w3.org/2001/XMLSchema#int"
[609,] "22^^http://www.w3.org/2001/XMLSchema#int"
[610,] "22^^http://www.w3.org/2001/XMLSchema#int"
[611,] "22^^http://www.w3.org/2001/XMLSchema#int"
```